SYLVICULTURE

IN THE

TROPICS

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PREFACE

This book was originally intended to form one of a series of volumes on Agriculture in the Tropics. The lamented death of its editor led to the abandonment of the series, but as considerable progress had been made with my contribution, it is now published as an independent volume.

The above statement must be my apology for the title of the book. Had I undertaken it on my own accord, I should have restricted its application to the portions of the Tropics and of the Sub-Tropics in which my own experience had been gained. However, I trust that what I have written will not be found to disagree with facts in other parts of the world which I am not acquainted with.

Before closing these preliminary remarks, I wish to acknowledge my particular indebtedness to the late Mr. W. R. Fisher's translation of Dr. A. F. W. Schimper's *Plant Geography*, to which I had constantly to refer while writing the first part of this volume; also to Sir William Schlich's several volumes of his *Manual of Forestry*, and to the *Manual of Indian Sylviculture*, by my old friend and mentor in Indian forests, Mr. E. E. Fernandez. A reference to my footnotes will show

how often I have had to turn to them for guidance, but even these are not sufficient for me to express fully what I owe to them.

For the chapter on soils I am much indebted to Dr. E. J. Russell's article on "The Soil and the Plant" in the last July number of *Science Progress*, and to a pamphlet on "Soils" by Dr. J. Nisbet which was appended to the *Indian Forester* some years ago.

With the exception of one photograph (viz. "Climbers in a riverside forest, Blue Nile"), which was taken by Mr. S. A. Wood of the Sudan Forest Department, all the others were taken either by my wife or by myself.

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WOODHOUSE, CHUDLEIGH,
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INTRODUCTION

SYLVICULTURE is the art of applying the knowledge of the requirements of different trees, in tending and regenerating existing woods or in rearing fresh woodland crops, and in working them to the best advantage of the forest owner.

In order, therefore, to create or work a forest crop in the best manner possible for that object, it is necessary first to study the different factors which may favour or stand in the way of proper development. In tropical countries especially, where vast areas under forest have been neglected for centuries, and where many adverse factors have combined in impoverishing them, a thorough study is required of the conditions which will enable the forester to lead them back to a healthier and more valuable state. Indeed, in such areas, the primary duty of the forester will be in arresting the decline of his forests, and to improve them so that they may ultimately be of the greatest utility to the owner.

Whether in rearing new crops or in tending and working older ones, be they in a healthy condition or deteriorated, it must be borne in mind that, even in tropical countries where the growth of trees is rapid, it takes only a short time to fell a tree, but several years to grow another one in its place; that mistakes, therefore, may take a long time in being set straight, and that no pains should be spared in avoiding them. For this reason, therefore, it is also necessary to study all

factors which govern the proper development of e growth.

It will therefore be convenient to divide this volume o the following parts :—

ART I. Factors governing and influencing the existence of forests ;
ART II. Formation and regeneration of woodland crops ;
RT III. Training and improvement of forests ; and
ART IV. Special measures of maintenance and protection.

The factors influencing the distribution of forests the "Soil," the "Climate," the "Locality," and Plant and animal allies and enemies." As "Man d domestic animals" are of sufficient importance to considered separately, they will be dealt with in a ecial chapter. I have also added a chapter on the Influence of forests on climate and locality."

PART I

FACTORS GOVERNING AND INFLUENCING THE EXISTENCE OF FORESTS

CHAPTER I

SOIL

THE functions of the soil in relation to plant life have not yet been fully determined. Of late years this subject has received a good deal of attention, particularly from American investigators, who have published the results of their researches in the Bulletins of the Bureau of Soils of the U.S.A. Department of Agriculture. In publishing these results they have also propounded theories which, however, have not been entirely accepted in this country. Before giving a short account of them it is necessary to relate what is known about the soil and its functions which make it possible for plants to grow in it.

In order, namely, that a plant may exist and thrive in a soil, it must be able to derive from it a sufficiency of air, of water, of warmth, and of food; it is also necessary that there be in the soil no such injurious substances as would poison the plant, and that the soil be sufficiently tenacious to allow the roots to take a firm hold of it and not to be pulled out by the action of wind and surface water.

All these factors are of equal importance; a lack of air is as detrimental to the plant as a lack of food, and the presence of toxic substances will make an otherwise fertile soil unfit for the growth of plants. Only, it must be remembered that what is sufficient for one species is not necessarily sufficient for another; that one species may grow in swampy land owing to its particular

structure, while others require more air from the soil and less water, and that a substance which may be injurious to a plant may not only not be harmful but may be beneficial to others. This is, for example, the case with lime, which is necessary to most plants, but a mixture of more than 4 per cent of which is injurious to the Sweet Chestnut.

In examining a forest soil it will be found that the top layer, which itself may or may not be covered with a matting of dead and decaying leaves, is of a dark colour, due to a large admixture of decomposed organic matter chiefly derived from dead leaves, fruit, twigs, and roots. Lower down it usually gets lighter in colour as this mixture decreases in quantity, and ultimately it is of the colour of the rock from which it is derived. This portion of the soil is known as the *sub-soil*, and the darker layer above as *surface-soil* or simply as *soil*. The black colouring matter in the latter, which is known as *humus*, is due to the decomposition of organic matter, such as dead leaves, roots, twigs, fruit, etc. This humus plays an important part not only in the production of plant-food, but in modifying the physical properties of the soil. Its beneficent attributes, however, depend on the thorough aeration of the soil, and if this be interfered with, as, *e.g.*, through an excess of water in the soil or by an absence of earthworms, the humus turns sour and only a limited number of plants can exist on it. Among the trees which will be found growing on such soils may be mentioned the Rhododendron. In the colder latitudes such a soil will turn to peat, but in the Tropics true peat is said not to form at an altitude lower than 1200 metres[1] (nearly 4000 ft.).

The poverty in humus of many tropical forest soils has repeatedly been commented on by different writers, especially as regards the soil in evergreen forests. Instead of finding, in these, a soil covered with a matting of dead leaves and other vegetable remains, the lower

[1] Schimper, *Plant Geography*, translated by W. R. Fisher, p. 382.

layers of which are in an advanced state of decomposition, the soil in these forests shows little sign of these organic remains. The cause of this is that, in evergreen forests, the leaf-fall is a much more gradual process than in forests the leaves of which all fall practically at the same time; that, owing to the relatively high temperature, decomposition goes on much more quickly than in colder latitudes; and that, owing to torrential rains, surface layers are much more liable to be washed away than where the rainfall is gentle.

According to their mineralogical origin, soils may be broadly divided into *clayey*, *limey*, and *sandy* soils respectively, but there are also numerous mixtures which may modify their chief characteristics sufficiently to earn for them separate nomenclatures.

Clayey soils, which consist of at least 50 per cent of clay, are rich in mineral constituents, and are capable of absorbing a large quantity of water. This faculty has, however, its drawbacks, for the absorption of water to a great degree means the exclusion of air, for it does not give up readily the water which it takes up. The soil, therefore, becomes water-logged, cold, and badly aired, and when it does dry it splits and cracks, and in so doing is apt to injure the roots and rootlets of plants growing in it. When underlying a more porous soil it first absorbs all the moisture which it derives from it, but does not let any through. If the water can then find an egress owing to the inclination of the strata, a spring is formed at the junction of the porous layer and the clay; but if the strata are cup-shaped the water, finding no egress, saturates the upper porous layer and the soil becomes swampy. The addition of lime to a clayey soil renders the soil more permeable, and in agriculture the liming of clayey soils is necessary for the cultivation of certain crops. Humus will also correct these physical defects to a certain degree and make the growth of certain trees possible, which otherwise would not be able to exist on heavy clay.

In the Tropics, the soil known as "cotton soil," which

covers large alluvial flats and depressions, and which is caused by the slow deposit of particles of clay by waters highly charged with them during flood time, belongs to the heavier soils. When properly tilled it is a very fertile soil for certain crops, and is particularly favourable to the cultivation of cotton; but untilled and unaired it is on the whole a poor forest soil, capable of supporting only a limited number of trees. Nevertheless some species, notably several species of *Acacia*, are able to form forests on cotton soil, such as, *e.g.*, *A. arabica* on the periodically flooded lands near rivers, the *A. Seyal* on somewhat higher lands, the *A. Suma* and *A. Seyal* var. *Fistula* in pans and depressions.[1]

Among other species which generally indicate a clayey soil may be mentioned the Tamarind (*Tamarindus indica*), some of the species of *Bauhinia* (*B. racemosa* and *B. reticulata*), several trees belonging to the natural order of the Ebenaceae (*Diospyros mespiliformis*, *D. Embryopteris*, *Maba abyssinica*, etc.), many of the Sapotaceae (*Bassia latifolia*, *B. longifolia*, *Butyrospermum Parkii*, etc.).

Limey soils contain 10 per cent or more of lime, usually present as a carbonate. They are fertile soils of a favourable texture for admitting air and water, but they have the drawback of often being rather shallow, and when lime is present in large quantities they let the water through too easily. But in proper quantities lime is favourable to the greater number of plants, although there are a few species which will not thrive when it is present in the soil. The forest flora is generally much richer on limey soils than others. Figs. 1 and 2 show the change of forest vegetation which occurs in adjacent portions of forest with a change of soil. They represent forest Blocks on the Blue Nile, Fig. 1 showing a crop of pure *Acacia Seyal*

[1] Recent chemical analyses of such soils, made at the Wellcome Tropical Research Laboratories at Khartoum, show that they are markedly deficient in organic matter and in nitrogen. Their black colour must be due, therefore, to that of the rock from which they are derived. In India, cotton soil is said to be the product of disintegration of trap-rock.

on cotton soil, while Fig. 2, which represents forest on limey soil, shows a mixed crop which is made up of *Anogeissus leiocarpus*, *Stereospermum Kunthianum*, *Dalbergia Melanoxylon*, and several others (not seen in the photograph), such as *Sterculia cinerea*, *Lonchocarpus laxiflorus*, *Adansonia digitata*, etc. The difference of effect of soil on vegetation is so marked

FIG. 1.—Pure forest of *Acacia Seyal* on cotton soil, Sudan.

that, even where small masses of the limey soil occur in the midst of the vast extent of cotton soil, the vegetation at once changes, and the *Acacia* gives way to the other species which favour a limey soil.

Sandy soils consist mostly, that is 75 per cent or more, of silica in the shape of disintegrated sand. They are soils which get hot quickly and cool quickly. They absorb water greedily, but they also give it up

readily unless prevented from doing so by an impermeable substratum of clay. They are the least fertile of soils, therefore the number of species which can grow on them is also limited, especially where the rainfall or other supply of moisture is scanty. In such places the soil loses its cohesiveness and stability, plants find

FIG. 2.—Mixed forest on limey soil, Sudan.

no anchorage in them, and, moving in front of prevailing winds, the sands advance in billows, which are a great danger to cultivation.

Where, however, a sufficient amount of moisture and cohesiveness is given to the soil, certain plants are able to spring up and exist, and among them such trees as the umbrella-shaped *Acacia tortilis*, although, as Fig. 3 shows, their hold on the soil is not very great, and

they are apt to be uprooted by sudden gusts of wind. With more moisture and with or without the help of certain measures, which will be described in another place, other trees and plants are able to establish themselves and to fix the soil. Thus in the Kordofan Province of the Anglo-Egyptian Sudan long ridges of sand, which had advanced from more rainless and more

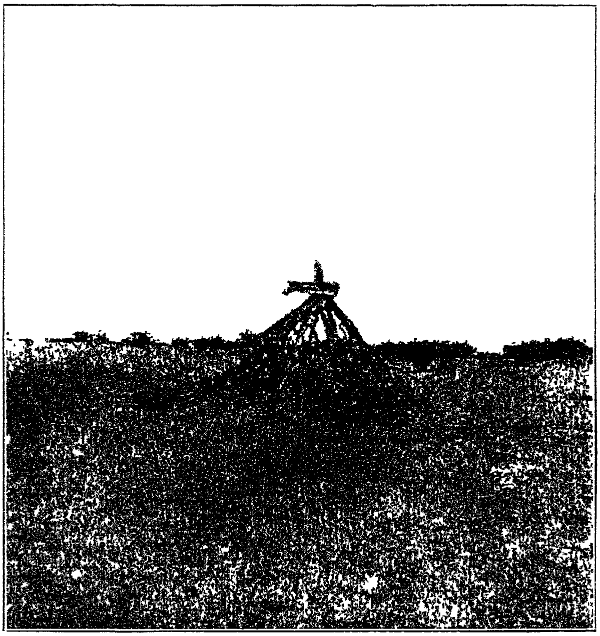


FIG. 3.—*Acacia tortilis* overturned by the wind.

windy districts, have clothed themselves with open forests of *Acacia Verek*, which supply the best gum-arabic of commerce. In Southern India the *Casuarina equisitifolia* has been used successfully in fixing shifting sands on the Madras coast, while in Ceylon the Palmyra palm (*Borassus flabellifer*) also gets a hold of sand-dunes in the Northern Province. There are instances where very fine-grained sandy soils, probably cemented by organic matter, are impenetrable to air and water.

Such soils are not suitable for plant growth, as they combine some of the defects of sandy soils with those of heavy clays.

Apart from these three classes of soil there are numerous mixtures which may contain, in varying proportions, clay, lime, and sand.

The *loams*, for example, are mixtures of clay and sand, and, according to whether clay or sand predominates, they are called *clayey loams* or *sandy loams.* They are among the most favourable for forest growth, for the sand corrects the impermeability of the clay, while the clay in the soil retains moisture which the sand is unable to keep.

For the Tropics no description of soil would be complete without a mention of one which is largely represented both in Asia and Africa, and which is known as *laterite.* It consists usually of a red clayey loam or loamy sand containing ferric oxide or ferric hydrate in varying proportions. It is considered a poor soil, but yet bears forests where the rainfall is sufficient.

Marls are mixtures of clay and lime and are of great value in agriculture. For this reason, where they are to be found, forests usually give way to field crops, but they are as excellent for tree growth as for agriculture.

Reference has been made above to the physical properties of the soil. I shall therefore recapitulate them. They are: (*a*) the faculty of absorbing and retaining water; (*b*) tenacity or cohesiveness; and (*c*) depth.

The *faculty of absorbing and retaining moisture* has a direct effect on the amount of air which can penetrate into the soil; a soil which gets gorged with water excludes the air, and as air and water are of equal importance to plant life, such a soil is even less favourable to plants than one which gives up its water too easily, for no soil becomes so dry that it does not retain some traces of moisture. Even air-dried samples

of sandy soil from the Kordofan sand-dunes, when analysed in the dry atmosphere of Khartoum, gave from 0·02 to 0·10 per cent of moisture.[1] In England, analyses carried on after drought gave higher results, viz. in clay soil without organic manures 11·9 per cent, and with annual dressings of manure 18·0 per cent, in heavy clay 20 per cent, and in sandy soil 7·6 per cent.[2]

According to the amount of moisture which is present in the soil, whether it be due to the size of the soil particles, their grain or texture, or to abundance or otherwise of organic matter, or whether it be due to flooding which may be caused by impermeable strata below or from inrush of water from above or from the sides, the soil may be classed as *wet* when all the available space not occupied by soil-particles is taken up by water, or nearly so. Likewise, by gradually reducing the amount of water in the soil, it passes through different gradations known as *moist*, *fresh*, *dry*, and *arid*. The most generally favourable to forest growth is a fresh soil, which should only leave traces of moisture on the hand when pressed. Such a soil contains an adequate supply of water and air to suit the majority of plants. Such as grow in wet soils must be able to content themselves with a small or intermittent supply of air, or they must furnish themselves with special processes by which their roots or stems can take up the necessary amount of air direct from the atmosphere. Such are pneumatophores, which we shall refer to later. In such soils, as well as in the driest, the plants have foliage which reduces transpiration to a minimum.

The *cohesiveness* of a soil, which denotes the amount of resistance which it offers to penetration by roots and also to air, moisture, and warmth, and the anchorage which it may give to the plants, depends largely on the mineralogical composition of the soil. Thus clays

[1] *Third Report of the Wellcome Research Laboratories at the Gordon College*, pp. 416 and 418.

[2] "Science Progress," No. 21; *The Soil and the Plant*, by E. J. Russell, D.Sc.

.layey loams and also marls form *heavy* soils and he most resistant, sandy loams and loamy limes .lled *mild*, loamy sands and sandy marls are *light*, ary sandy soils *loose*, and those which are liable moved by the wind are called *shifting*.

he *depth* of a soil has considerable importance in ,ry. It can be gauged according to the distance iich the roots can penetrate and at the same time ipplied with the necessary amount of oxygen. rally speaking, a deep soil favours the development ie root-system and a corresponding development e bole or stem of a tree. Such a soil is particularly ed for such trees as develop a long taproot, and a c in this development may result in the tree dying ı from the top, or becoming, as it is called, "staged." On shallow soils, trees are short-boled and rally slow growing. In the Tropics, where shallow quickly dry up and get much heated, the number oecies capable of growing in them is restricted to as are leafless during the greater part of the year 'hich store their own water in their stems, and to e evergreens. In such soils are found different ies of *Cactus* and *Euphorbia* among the succulent ts, and a certain number of trees belonging to the ıral orders of the Combretaceae (*Gyrocarpus* and *›geissus*) and Burseraceae (*Boswellia* and *Balsamodron*), etc. Several species of *Ficus* are also ıd growing on shallow, rocky soils, but they have 'erful roots which insert themselves into the fissures the rock, and are able to force themselves into the .ster depths.

It is really very difficult to say what, in the Tropics, lly constitutes a deep or a shallow soil. French esters consider a soil very deep when it ranges over centimetres (3 feet) from the surface, but in the ›pics such a general classification cannot be adopted ing to the much greater range of distribution of isture. A soil which may be deep in a damp locality y be comparatively shallow in a dry or arid situation,

and that which is deep for one species may be shallow for another. As an example may be cited the Jhand (*Prosopis spicigera*) of the Panjab, which sends its taproot sometimes to a depth of 27 metres (90 feet), while, in digging a well in Oudh, roots of Sāl (*Shorea robusta*) were found to have penetrated to a depth of 18 metres (60 feet).

The above remarks will suffice to show how important the physical properties of a soil are with respect to plant life; indeed, it is generally agreed that they are the most important factors. American authors go so far as to make soil fertility chiefly dependent on physical properties and on the presence or absence of injurious ingredients in the soil.

Apart from the carbon which the plants derive through their leaves direct from the atmosphere, they obtain from the soil certain nutritive substances which are compounds of calcium, potassium, sodium, nitrogen, magnesium, phosphorus, iron, and a few others. This food, as far as evidence is available, is taken up in a solution made by the carbonic acid generated by micro-organisms or by plant roots.[1] It has also been proved that the addition to the soil in the way of the organic manures, and also of nitrates, phosphates, potassium salts, and calcium carbonate, increases the strength of a crop.

The American theory is, then, that the soil is formed by the disintegration and not by the decomposition of rocks, and that all soils are able to yield the same soil solution, containing all that is necessary to plant food, and that what is taken up by the plant is replaced in the solution from the soil. The chief difference between the different soils is in the manner in which the soil solution is yielded to the plants, this degree being dependent on the texture or grain of the soil and on the presence or absence of toxic substances. The addition of manures has the effect of improving the grain and in removing or oxidating the toxic substances. It is also contended that if a soil be allowed to lie

[1] Dr. E. J. Russell, *loc. cit.* p. 136.

fallow for a sufficient time the toxic matter in the soil will be removed. The formation of humus in a forest soil would have a similar effect to artificial manure on texture and on toxic substances.

These toxic substances which exist in the soil are said to be largely due to excretions from plant roots, and it is explained that the plants do not poison themselves because the roots are constantly on the move searching for food, and fresh areas are constantly being tapped. It is the tip of the root which absorbs the solution, and as it is only capable of performing these functions for about four days, it must extend itself in order to be able to continue these functions, and thus the poison-impregnated soil is left behind.

The toxic substances excreted by a plant are said not to be necessarily toxic to other species. It is held, on the contrary, that the cultivation of other crops will sweeten the soil and render it capable of again rearing those which had been excluded owing to the excremental toxins which they had given out.

These arguments, although they are admitted by English experts to help in the true solution of the functions of the soil towards the plants, are by no means accepted in their entirety. For example, as regards plant excretions, no evidence has been found to prove that they exist. At Rothamsted[1] wheat has been grown continuously in one plot since 1843, and the young plants show no signs of poisoning ; and other experiments failed to show any such effects on crops grown several times in succession in the same soil. As regards soils which were grown in rotation and with one year fallow, the wheat certainly gave astonishingly good results, but, on the other hand, turnips did not. Some other causes for the diminution of soil fertility must, therefore, be looked for.

Dr. Russell[2] disagrees with American experts that the soil solution is the same in all soils, and says :

[1] Dr. E. J. Russell, *loc. cit.* p. 148.
[2] *Ib.* p. 150.

"Other chemists consider that the soil is more complex, containing colloidal decomposition products and a solution which not only differs in composition in different soils but also shows local variations in composition in different parts of the same soil." It is therefore considered that while the infertility of a "sour" soil may be due to the presence of toxic substances, great importance should be attached "to the nutritive functions of the soil constituents and of added fertilisers."

The same author considers that where the American writers have gone wrong is in ignoring the biological changes going on in the soil, and the functions of the nutrient material which arises in the soil from the decomposition of organic remains by the action of micro-organisms.

The most important contribution to our knowledge is the recognition of the fact that, more than chemical composition, the physical properties of the soil, which depend on the size of the soil-particles and the consequent regulation of warmth, air, and water-supply to the plants roots, are more important in determining the value of a soil for plant life.

In Forestry, artificial improvement of the soil by means of fertilisers is hardly practicable, except over limited areas, such as nurseries and plantations. The crop has therefore to depend on the humus which is formed mostly from fallen leaves, fruit, twigs, etc., and from the decomposition of roots and root-fibres. The timber in a tree happily contains only a small proportion of the rarer nutrient constituents of the soil, and what comes back to the latter in more concentrated form is sufficient to keep up the nutrition of the crop, while at the same time improving its physical properties. It is for this reason that such customs as the removal of leaves, dead or alive, for manure or litter is harmful to the forest and should be discouraged. In the same way, the too-sudden removal of the leaf-canopy by clear-fellings not only stops the supply of vegetable débris,

but leaves the soil exposed to sun, wind, and rain, and thus interferes with the gradual decomposition of the organic remains on the soil. Weeds are also apt to spring up, which not only stifle young forest growth, but are apt to interfere with the proper aeration of the soil and nutrition of the forest crop. Grazing on level lands causes the soil surface to be beaten down hard and thus to exclude air, while on slopes it loosens the surface which gets washed away. Forest fires consume the organic remains, and although part of their ash is left behind, the physical properties of ash are not the same as those of humus, and the soil deteriorates.

CHAPTER II

CLIMATE

THE regions of the earth's surface contained between the Tropic of Cancer and that of Capricorn, *i.e.* approximately between twenty-three and a half degrees north and south of the equator, respectively, are said to be within the Tropics. Within this zone the sun during part of the year is at noon to the south, and during part to the north. The nearer the locality is to the Tropic of Cancer the shorter will be the number of days when the sun is to the north at noon, while the reverse is the case with localities to the south of the equator. Owing to the greater velocity with which the earth revolves near the equator the sun rises and mounts to a high angle quickly and sets as suddenly, and twilights are, consequently, of much shorter duration within these regions than in those farther from the equator. It also follows that the intensity of light within these regions is also greater.

The lengths of days and nights are much more even in this than in more distant zones, where in summer the days are much longer, and in winter much shorter. The nearer to the equator the more even will be the division between day and night at all times of the year, and, consequently, the more even will be the climate. The division of the year into seasons will therefore be much less marked, or may be made apparent chiefly by the direction of the prevailing winds or the intensity of the rainfall.

The *distribution of rain* within the Tropics, which may vary from practically nothing in deserts to 5000 millimetres (200 inches) or more, is, as a rule, also greater and more evenly distributed near the equator, and the humidity of the air will be here greater also. Within the Tropics the rain falls usually during well-defined rainy seasons. In a few localities the distribution of the rain may be fairly even throughout the year, *e.g.* in Singapore; or there may be two more or less even rainy seasons, as in New Guinea[1] or on the south-western coast of Ceylon; or, more generally, if there are two rainy seasons, one is much shorter than the other; and, in other places, there may be only one rainy season. In the more desert countries the rainfall is very small, and the only indication of the rainy season may be moist winds blowing from the direction of the equator. Thus at Khartoum, which has a rainfall of only about 125 millimetres (5 inches), the south wind, which is comparatively moist, blows fairly steadily from May to October, and there are not more than half a dozen rainy days during that period.

It must not be imagined, however, that the rainfall increases uniformly and gradually everywhere towards the equator, for there are local factors, especially in the way of mountain ranges, which have a strong influence in determining the amount of rainfall which will be precipitated. Thus, in Ceylon, where the mountains rise fairly abruptly in the south-western portion of the island, the eastern slopes being more gradual, the south-western portion gets both the S.W. and N.E. monsoons, and the rainfall ranges from about 2000 millimetres (80 inches) to about 7500 millimetres (300 inches), while on the eastern and south-eastern side it will only range from 875 mm. (35 inches) to 2250 mm. (90 inches), with practically only the N.E. monsoon to depend on. The same rule applies to the western (Malabar) coast of India as compared with the eastern (Coromandel) coast. All over the Tropics a similar rule applies: in South

[1] Schimper, *Plant Geography*.

America the rainfall is heavy on the sierras on the east coast, while the rainfall decreases on their western slopes, and only increases again when the still higher ranges of the Andes cause fresh precipitation of rain. And so on in other continents.

The *saturation of the atmosphere* or its *relative humidity* is greatly dependent on the amount of rainfall, although, as will be seen later, it is also increased by the neighbourhood of large sheets of water, such as the sea, lakes, or rivers. Thus the relative humidity in the Nile basin increases from a mean of 34 per cent in the morning and 20 per cent in the afternoon, for the year, at Assouan, which is just outside of the Tropics, to 80 per cent in the morning and 68 per cent in the afternoon at Bakoba on Lake Victoria.[1]

Yet another factor having a bearing on forest vegetation is the *range of temperature*; yet, within the Tropics, it is not of the same importance as in other zones, as the extremes are not as great. According to Schimper,[2] the differences between the mean temperatures of the hottest and coldest month near the equator lies between 1° and 5° centigrade (1·8° and 9° Fahr.), and does not exceed these figures even in the interior of continents, and, according to him, even towards the limits of the Tropics, and in the extremest climates met within the Tropics, the annual variation hardly exceeds 13° C. (23·4° Fahr.). The latter statement is not entirely borne out by observations made in the Nile basin,[3] for in the northern part of the Sudan, at Wadi-Halfa, the difference between the hottest and coldest month is over 18° C. (32·4° Fahr.), while at Assouan it is 19° C. (34·2° Fahr.). It must also be borne in mind that although close to the equator the mean diurnal range may not exceed 13° C. (23·4° Fahr.), *i.e.* from 17° to 30° C. (62·6° to 86° Fahr.), this range may vary, *e.g.* at Berber, from 9° C. (48·2° Fahr.) in January

[1] Captain H. G. Lyons, *The Physiography of the River Nile and its Basin*, 1906.
[2] *Op. cit.*, transl. p. 213.
[3] Captain H. G. Lyons, *op. cit.*

to 44·5° C. (112·1° Fahr.) in June. This does not represent the extremes of temperature in these regions where the thermometer sometimes falls to freezing-point in winter while it may rise to 46·5° C. (115·7° Fahr.). Plants growing in these regions, therefore, require to be able to stand very low as well as very high temperatures.

The *elevation above the sea-level* is another climatic factor affecting the vegetation, but within the Tropics its influence is not much felt at below 600 metres (2000 ft.) or more, according to whether a region is nearer to or more distant from the equator; and it is mostly in mountain ranges that differences of vegetation will make themselves felt with distinctness. The subject will be dealt with, therefore, under the head of "Locality."

To resume, the climatic factors chiefly influencing forest vegetation are: (1) rainfall, (2) relative humidity of the atmosphere, and (3) range of temperature. As, however, with an increasing rainfall the humidity of the air is also increased, and to a certain degree also the range of temperature, it is convenient to describe the forests of the Tropics according to zones of rainfall which have each their characteristic vegetation. These zones can be classified as follows:—

1. Desert zone	with a rainfall of		0 to 100 mm.	(0 to 4 inches).
2. Arid zone	,,	,,	100 to 400 mm.	(4 to 16 inches).
3. Dry zone	,,	,,	400 to 1000 mm.	(16 to 40 inches).
4. Moist zone	,,	,,	1000 to 1900 mm.	(40 to 75 inches).
5. Wet zone	,,	,,	over 1900 mm.	(over 75 inches).

The *desert zone* is not favourable to the existence of forests. The vegetation consists generally of a few scattered herbaceous plants with long taproots or succulent plants, which store up their water; only in depressions, such as the dry watercourses, can narrow fringes of shrubby trees be seen occasionally. Except, therefore, where water can be supplied from other sources than rainfall, this region is of little interest for the forester.

In the *arid zone* woody growth begins to establish itself, but is usually confined to shrubby or small trees, mostly of a thorny character, leafless during the driest part of the year, and when in leaf often provided with a light feathery foliage which reduces transpiration to a minimum. In America especially, this zone is also characterised by succulent Cactaceae, such as *Opuntia* and *Cereus*, while on rocky ground and shallow soils, both of the Old World and the New, woody succulent Euphorbias also establish themselves.

FIG. 4.—Open forest of *Acacia Verek*, Sudan.

This zone, therefore, does not lend itself much to timber production, but is of importance to the forester on account of the minor produce obtained from its trees. Such are gums and frankincense, the former obtained largely from Acacias and the latter from genera of the Burseraceae, such as *Balsamodendron* and *Boswellia*. The best gum-arabic of commerce is obtained from the *Acacia Verek* (also called *Acacia Senegal*), which forms open low forests near Gedaref, and on the sandy dunes of Kordofan, in the Anglo-Egyptian Sudan, and also in

Senegal (Fig. 4). The *Balsamodendron* and *Boswellia* are also found in the next zone, but in dry rocky situations.

The *dry zone* may be said to be the home of the "savannah forests." These forests are generally somewhat open in character, with the spaces not only between but under the trees filled with various grasses and other herbaceous plants and shrubs. It is in this zone that large trees begin to be met with, *e.g.* various Acacias, the Baobab or Monkey-bread tree (*Adansonia digitata*), the Sausage tree (*Kigelia*), African Mahogany (*Khaya* spp.), etc. These forests are sometimes thorny and may be pure, such as those of *Acacia planifrons* in S. India, and near Mannar in Ceylon, or, more commonly, they are composed of a variety of species, the majority of which are leafless during the driest months of the year.

Other local factors, such as the constant comparative humidity of the air, as in the case of forests growing not far from the sea, may change the character of these forests. In Ceylon, for example, the forests growing within this zone are to a large extent evergreen, although certain dry-weather leaf-shedders are found scattered through them. From an economic point of view these forests are capable of yielding major produce, such as timber and firewood, and several species yield minor produce in the shape of tanning material, fibres, gums and gum-resin, catechu, and even in some cases (*e.g.* *Landolphia owariensis*) rubber.

The *moist zone* is an important one with respect to forests. These are generally composed of deciduous trees varying from open savannah-forest to dense forests, such as those formed by Sāl (*Shorea robusta*). In India and Ceylon it is the typical forest-zone and contains most of the valuable timber trees such as Teak (*Tectona grandis*), Sāl (*Shorea robusta*), Satinwood (*Chloroxylon Swietenia*), Ebony (*Diospyros Ebenum*), Trincomalie-wood (*Berrya Ammonilla*), etc. Near the coasts where the atmosphere is more charged with humidity a larger

number of evergreen trees are found in mixture, such as *Mimusops hexandra* (Fig. 5), *M. Elengi*, Ebony, several species of *Memecylon*, *Pleurostylia Wightii*, *Nephelium*, *Sapindus*, etc.

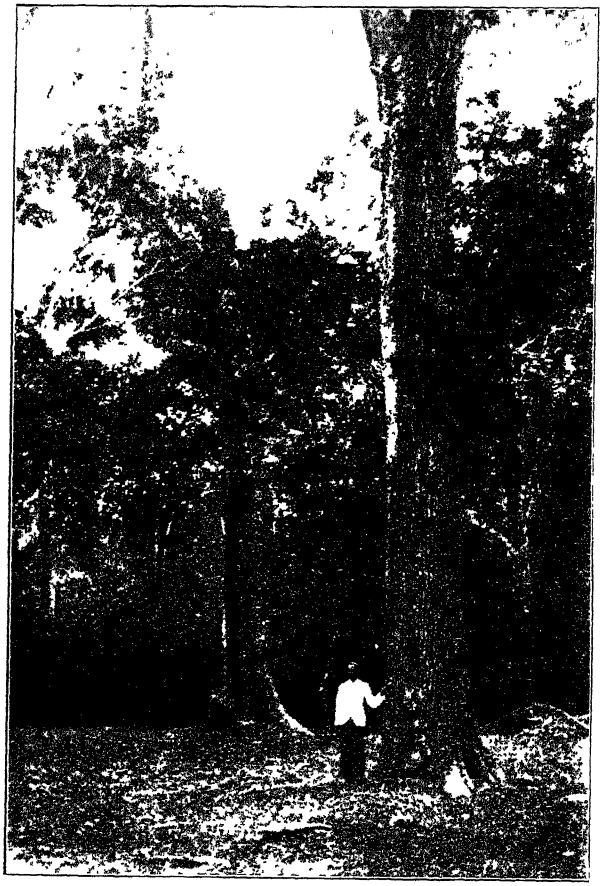


FIG. 5.—Moist zone evergreen forest in Ceylon; *Mimusops hexandra* in foreground.

In Africa the character of the forest within this zone varies a great deal. On the central African plateau the undulations of the ground are often very scantily covered, or there may be large stretches of somewhat

open forest with scattered large trees such as *Khaya* spp., *Parkia filicoidea*, *Daniellia thurifera*, *Berlinia acuminata*, *Afzelia africana*, *Tamarindus indica*, *Erythrophlaeum guineense*, with a variety of species belonging to the natural order of the Combretaceae and numerous shrubs. It is in this zone that a large number of rubber-yielding creepers will be found festooning the trees, such as *Landolphia* spp. and *Clitandra* spp., also the rubber-yielding tree *Funtumia elastica.*

According to Schimper[1] high forest does not occur except where the rainfall is 1800 millimetres and over. By this, I presume, he means forest composed largely of tall trees standing so close together that their crowns meet, or, in forest parlance, that they form "leaf-canopy." No doubt, although on the central African plateau the slopes and summits of the undulations are steppe-like or covered with an open growth of trees, yet the bottoms of the valleys are frequently filled with dense growths of trees, such as the "gallery-forests" of Schweinfurth,[2] but they derive a large proportion of their moisture from the watercourses whose banks they line.

In tropical America, according to Schimper,[3] this zone is also represented by an open kind of forest, known, according to the locality, as "campos," "llanos," "caatinga," or "savannah," and composed largely of deciduous trees including, towards the north, a number of Cactaceae and Euphorbiaceae, while towards the south the trees are leafless only a very short time. Heavy forest is mostly confined to bottoms of valleys. This zone is important economically on account of the rubber-yielding trees which grow within it, the "Ceara-rubber" tree or "Maniçoba" (*Manihot Glaziovii*, *M. dichotoma*, *M. piyauhensis*, etc.) and the "Para-rubber" tree (*Hevea braziliensis*) being the more prominent, the former in the open savannah forests of Northern Brazil, and the latter in the basin of the Amazon.

[1] *Plant Geography.* [2] *Heart of Africa.* [3] *Plant Geography.*

In Australia the forest in this zone is generally of an open character, that is, a savannah-forest, and consists largely of Acacias and Eucalypts. The latter are said to be characterised by the largeness of their fruit, which is usually urn- or pitcher-shaped.[1] I am, unfortunately, unable to give a more detailed description of these forests, the economic importance of which, so far, is evidently not considered to be great. It is in these open forests in North Queensland that is found the Myallwood (*Acacia homalophylla*), the wood of which is scented like violets. The bark of several of the Acacias or "wattles" is largely used for tanning.

The *wet zone* is that in which will be found dense forests, mostly evergreen, formed of trees growing with clean boles up to a great height. These forests are those described as "virgin-forests" by early writers, and, in consequence, this term always conjures up a vision of sombre vistas, like the nave of a cathedral, the pillars formed by enormous boles of trees soaring up into the dim and religious half-light caused by the interlacing branches forming the vault of the fane. In Africa, in the Great Congo forest described by Stanley,[2] this type is found in its most severe form. Large buttressed trees with clean boles scantily covered by epiphytic growth form the bulk of the crop; here and there gigantic lianas climb into the soaring crowns of the trees, while smaller growths of shrubs or herbaceous plants are scanty and the eye travels far into the sombre depths of the forest.

In other parts of the Tropics the architecture, if it may be called so, is more ornate and florid; the boles of the trees are adorned with epiphytic orchids, ferns, festoons of Lycopodiaceae, climbing plants belonging to the Pandanaceae, Araceae, Piperaceae, Melastomaceae, etc., and numerous lianas climb into the crowns. In some places graceful palms struggle up to the light, while the floor of the forest may be covered with a

[1] *Australian Handbook*, 1903.

[2] *Darkest Africa*. See also Schimper, *Plant Geography*, ch. iv.

dense growth of shrubs and herbaceous plants, ferns, etc., through which a path can only be cleared with the help of a knife (Fig. 6). The humidity of the air manifests itself in the abundance of filmy ferns, such as *Trichomanes* and *Hymenophyllum*, the latter clustering, like moss, on the trunks of the trees. In the higher forests large festoons of mosses and lichens hang from the branches of the trees.

In the Indo-Malayan region, this zone is characterised by trees belonging to the natural order of the

FIG. 6.—Wet zone undergrowth in a Ceylon forest.

Dipterocarpaceae. This family, which extends into the sub-tropical zone, both according to latitude and to elevation above sea-level, and into the moist zone, where it is represented by the Sāl tree (*Shorea robusta*) of India, and the *Vatica obscura* of Ceylon forests in the east of the island, is found as far east as New Guinea, and is represented by the greatest number of species in the Malayan peninsula and in the Malay Archipelago. With the exception of a single species of *Vateria*, which is found in the Seychelles, the natural order is not represented west of the Indian peninsula, unless the

very doubtful genus of *Monotes*, which is found in Africa and seems to be more nearly allied to the Tiliaceae,[1] is ascribed to it. Brandis[2] divides them into three groups, viz.: western, eastern, and of general distribution. The western group is represented by the genera *Vateria*, *Doona*, *Stemonoporus*, and *Monoporandra*, the last three of which are endemic in Ceylon. In the eastern group, and found within the Malay peninsula and Archipelago, in the Philippines, and New Guinea, are fifteen species of *Anisoptera*, while the last named is excluded from the domain of the species of *Parashorea*, *Pentacme*, *Dryabalanops*, *Isoptera*, and *Pachynocarpus*. The main group, with a more universal distribution, contains the important genera of *Dipterocarpus*, *Hopea*, *Shorea*, *Balanocarpus*, *Cotylelobium* (*Sunaptea*),[3] and *Vatica*.

Several of these trees are gregarious and form more or less pure forests, as we have already seen of Sāl in the moist zone. In this zone several species of *Dipterocarpus*, notably the Eng tree (*D. tuberculatus*) of Burma and the Hora (*D. zeylanicus*) of Ceylon, also *Vatica obscura* and *V. Roxburghiana* of Ceylon, form pure forests. Some forests, although not exclusively or almost exclusively composed of one species, are almost entirely made up of members of this natural order (Fig. 7). In some of the moister forests of Ceylon I have seen portions composed almost entirely of different species of *Doona*, with a free admixture of *Dipterocarpus*, *Shorea*, *Stemonoporus*, *Hopea*, and, along rocky gullies, *Vateria*.[4] Economically, this natural order is of very great importance. Many of its members are stately timber trees uniting to great size a great strength of fibre, while numerous by-products are obtained from them, such as camphor, which is deposited in the shape

[1] Dr. Heim, *Recherches sur les Diptérocarpacées*, 1892.
[2] *Sitzungsberichten der niederrhein. Gesellsch. f. Natur- u. Heilkunde zu Bonn*, Jan. 20, 1896.
[3] Trimen, *Flora of Ceylon*.
[4] In the Philippines it is estimated that 70 per cent of the total standing timber in the islands consists of trees of this family.

of crystals in cavities in the wood of *Dryabalanops aromatica*; gum-resin, used for varnish and for dammar, as in several species of *Shorea*, *Doona*, and *Diptero-carpus*; wood oil, as in *Dipterocarpus turbinatus* and

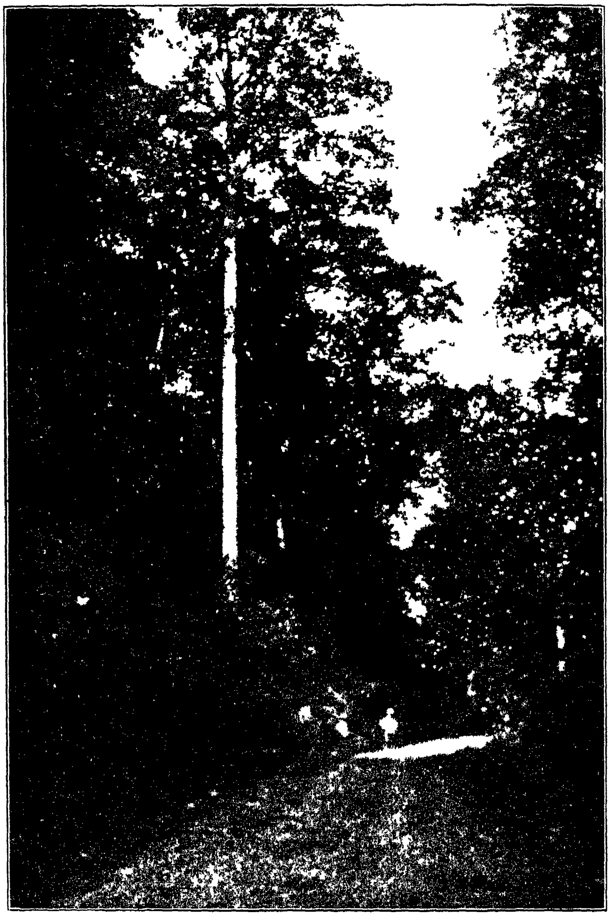


FIG. 7.—Wet zone in Ceylon. Forest of *Dipterocarpus zeylanicus* and *D. hispidus*.

D. glandulosus; fat or tallow which is obtained from various species of *Shorea* in the Malay Archipelago;[1] and edible fruit as with *Doona trapezifolia* in Ceylon.

[1] Brandis, *Indian Trees*.

The tribe of the Bamboos, which is also well represented in the sub-tropical and even in temperate zones, finds in this wet tropical zone its greatest development, especially in the Malay peninsula, and, with the dense leaf-canopy which it is able to form, it encroaches on the forest and in places drives other species away. It is found of all sizes, from the small *Arundinaria* of the mountain zone to the gigantic *Dendrocalamus Brandisii*, with culms up to 120 feet long, of Burma. In Burma bamboos are of the greatest economic importance to the people, who use them for all manner of purposes, such as all parts of a house (posts, beams, plaited walls and floors, thatch, etc.), as well as for household utensils and weapons.

Generally speaking, the forests of this zone, in Asia, are made up of a very great variety of species, most of them evergreen, in order to be able to resist the effects of heavy transpiration; many of the trees attain a very great size, and many are strongly buttressed (Fig. 8).

Among the trees not already mentioned above, the following can be cited for the low country: *Tetrameles nudiflora*, *Canarium* spp., *Mangifera* spp.; several Guttiferae, such as *Mesua*, *Garcinia*, and *Calophyllum*; Ebenaceae, such as many species of *Diospyros*, *Maba*, etc.; Meliaceae, such as *Chickrassia*, *Amoora*, *Melia*, etc.; Urticaceae, such as *Ficus*, *Celtis*, and *Artocarpus*; Sapotaceae, such as *Palaquium*, *Isonandra*, and *Bassia*; Leguminosae, such as *Albizzia*, *Pterocarpus*, *Parkia*, *Pericopsis*, and *Cassia*; Dilleniaceae, such as *Dillenia* and *Wormia*; Palmae by *Caryota*, *Areca*, and *Calamus*; while higher up will be found a number of species of *Eugenia*, *Calophyllum*, *Gordonia*, *Michelia*, *Symplocos*, *Vaccinium*, and *Elaeocarpus*; *Rhododendron* is found in more exposed places, and the undergrowth is in many cases a dense thicket of *Strobilanthes* or small bamboo.

Many of the trees are of great economic value for their timber, which, however, is usually heavy (such as *Mesua*, *Calophyllum*, *Palaquium*, *Pericopsis*, *Gordonia*, *Chickrassia*, *Michelia*, and *Pterocarpus*), while

some give valuable by-products, such as gutta-percha (*Isonandra* and *Palaquium*), gum-resin (*Canarium*), gamboge (*Garcinia*), jaggery or sugar and toddy (*Caryota*), rattan (*Calamus*), and edible fruit (*Garcinia*).

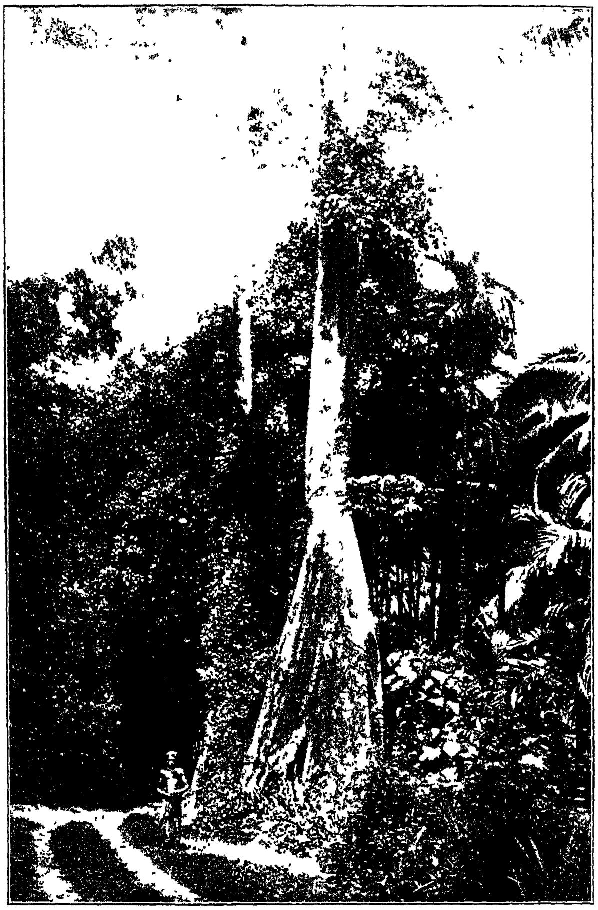


FIG. 8.—Buttressed tree of the wet zone. *Tetrameles nudiflora.*

I have described above only what may be called the virgin-forests; there are also numerous forms of secondary growths caused by other factors, which will be described later.

In describing the Great Congo forest, which may be taken as the type of the West African wet-zone forest, Stanley[1] says :—

"Imagine the whole of France and the Iberian peninsula closely packed with trees varying from 20 to 180 feet high, whose crowns of foliage interlace and prevent any view of sky and sun, and each tree from a few inches to 4 feet in diameter. Then from tree to tree run cables from 2 inches to 15 inches in diameter, up and down, in loops and festoons and W's and badly-formed M's; fold them round the trees in great coils until they have run up the entire height, like endless anacondas, let them flower and leaf luxuriantly, and mix up above with the foliage of the trees to hide the sun, then from the highest branches let fall the ends of the cables, reaching to near the ground by hundreds with frayed extremities, for these represent the air-roots of the Epiphytes. . . . Where the forest is compact as described above, we may not do more than cover the ground closely with a thick crop of phrynia and amoma, and dwarf bush; but if the lightning, as frequently happens, has severed the crown of a proud tree, and let in the sunlight . . . or a tornado has been uprooting a few trees, then the race for air and light has caused a multitude of baby trees to rush upward—crowded, crushing, and treading upon and strangling one another until the whole is one impervious bush."

This picturesque description is confirmed by later forest reports,[2] which show that where the typical virgin forest, unfortunately destroyed in many places, is still to be found, the overhead cover is so dense that the floor of the forest is not crowded with low growth, and that this type of forest differs in this respect from the forests of the moist zone in Asia or America. From these same reports we gather that, except for a few

[1] *Darkest Africa*, vol. ii.

[2] *Report on Forest Administration in South Nigeria for 1906*, and *Report on Forests of the Gold Coast*, both by N. H. Thompson, Conservator of Forests.

species which shed their leaves periodically, the majority are evergreen. Some of the trees from the moist zone are also found to extend into this, such as *Khaya senegalensis* and *Detarium senegalense*, the timber of both of which is exported under the name of "African mahogany," *Funtumia elastica*, *Diospyros mespiliformis*, etc.; while among the other important trees may be mentioned some other species of *Khaya*, *Pseudocedrela* ("scented mahogany"), *Afzelia*, *Tetrapleura*, *Chlorophora excelsa*, *Lovoa excelsa*, possessing a timber not unlike that of teak, *Terminalia*, *Mimusops*, etc.; while among the lianas there are *Landolphia owariensis* and *L. Droogmansiana*? yielding good rubber, and others of the same genus, *Clitandras* and *Carpodinus*, giving inferior rubber. The oil palm, *Elaeis guineensis*, is also characteristic of this zone.

On the eastern side of the continent the forests do not, as a rule, take quite such fine proportions, except perhaps under special conditions, such as proximity to water. The country is more broken up by stretches of savannah and savannah forest, due partly to drier climate and soil, and partly to fires. This theory is supported by various writers, such as Signor Philippi,[1] and by Sir Harry Johnston.[2] The latter says:—

"I am sometimes led to believe that the whole of Africa was once covered with more or less dense forest, but that the climate of the eastern half of the continent being drier than in the west, the ravages of bush fires started by man have made greater headway than the reparatory influence of nature. Only in specially favoured tracts enjoying exceptional rainfall, or else provided with underground springs, could the forest always remain green and full of sap all the year round, and thus be able to choke out the fire, or, in the wet season, to make sufficient growth to repair the ravages sustained by bush fires."

But this is a subject which we shall refer to, later on, in its proper place. The species of the trees composing

[1] Ruwenzori: *Duke of the Abruzzi's Expedition.* [2] *British Central Africa.*

this portion of the zone do not seem to be very different from, although less abundant than, those found in the western part, excepting on higher elevations, where there is a special flora which will be described later under the head of "Influence of Elevation on Forest Growth."

In tropical America this zone is characterised by the exuberance of growth which called forth the admiration and wonder of early explorers. According to Schimper,[1] who has visited both these forests and those of the Indo-Malayan region, the essential features of both are similar, but the trees grow to larger dimensions in tropical America, the liane-stems are thicker, and there is a greater abundance of epiphytes. From many of these depend an immense number of aerial roots "descending vertically and unbranched through the air, forming lightly stretched cords, connecting the climbing and epiphytic Araceae and Clusiaceae with the nutritive soil."

Among the more notable of the species in these forests in Brazil, Spix and Martius[2] give us the following: The large silk cotton tree (*Bombax pentandrum*), relatives of which are found in the African and Indo-Malayan forests; *Lecythis Ollaria*, *parviflora*, *Anda braziliensis*, *Bignonia chrysantha*, *Spondias Myrobolanus*, *Sapindus Saponaria*, *Cedrela odorata*, the "Chilian fir" (*Araucaria imbricata*), etc.; while among the shrubs are some Myrtaceae, many Rubiaceae, etc. The above description shows a great similarity in the way of genera to the forests of the Indo-Malayan region, only Dipterocarps are absent.

In more northern forests than those described by Martius we find the Mahogany tree (*Swietenia* spp.), which in Guiana and British Honduras and the West Indies is a most important article of commerce, as well as Greenheart (*Nectandra Rodioei*), which is the best wood for resisting attacks of the teredo; Logwood (*Haematoxylon campechianum*) is also an important article of export from British Honduras.

[1] *Op. cit.*, ch. iv.

[2] *Travels in Brazil*, by Dr. J. B. von Spix and Dr. C. F. P. von Martius.

In tropical Australia the wet zone is confined to the slopes on the north-east coast and to a small strip in the northern part of the northern territory. The tree flora here belongs to the same type as in the Indo-Malayan region, many of the genera being identical (and in some cases even the species being the same). Among other of these genera can be mentioned: *Cedrela Elaeocarpus*, *Calophyllum*, *Pittosporum*, *Terminalia*, *Albizzia*, *Alstonia*, *Gmelina*, *Sarcocephalus*, and *Cinnamomum*. Added to these there are a large number of Eucalypts (some sixty species in Queensland), the conifers being represented by *Podocarpus* and *Araucaria*, and *Acacia* by several species.

Excluding Eucalypts, among the best-known timber trees are:[1] the Red Cedar (*Cedrela Toona*), the Bean tree (*Castanospermum australe*), Tulip wood (*Harpulia pendula*), Yellow wood (*Sarcocephalus cordatus*), Swamp Mahogany (*Tristania suaveolens*), the Tea tree of Queensland or Paper bark of northern territories (*Melaleuca leucadendron*), and several others, while Spice barks (known locally as Sassafras) are obtained from two species of *Cinnamomum*, and the barks of several Acacias are used for tanning.

To sum up shortly, we have in the *desert* zone hardly any vegetation at all. What there is consists mostly of thorny hard herbs and undershrubs widely scattered, or, in depressions, a few thorny shrubs. In the *arid* zone the vegetation is also mostly thorny and occasionally fleshy; trees are few or small, and the foliage is deciduous through the drier months. Often, in order to reduce transpiration, it is finely pinnate or bipinnate, and occasionally it is coriaceous and persistent. Grass covers the greater part of the ground, but dies soon after the rains. This is a region of "savannahs" passing into "thorn-forest."[2] In the *dry* zone trees begin to take a better development. The forest

[1] *Australian Handbook*, 1903.

[2] These terms, used in this summary, are adopted from Schimper's *Plant Geography*.

is still somewhat open with deciduous trees, thorny in places. It is mostly savannah-forest. The *moist* zone is one of the most important forest zones. The trees, composed largely of dry-season leaf-shedders, grow fairly close together, and can form good forest. It is the "monsoon-forest." Lastly, in the *wet* zone the trees, largely composed of evergreens, often buttressed, grow tall and close together. Lianas and epiphytes attain their greatest development in this zone, and palms and tree-ferns are also more abundant than in other zones. These forests are called "rain-forests."

Before closing this chapter it is necessary to add that the failure of the monsoon rains may gravely affect the character of the forest. In two articles in the *Indian Forester*, Mr. R. S. Pearson[1] describes the damage done by the drought of 1899-1900 to the forests in the Panch Mahal forests of the Bombay Presidency. It appears that the trees most quickly affected were those with superficial roots, while those with taproots resisted the drought better. Among those most affected were Teak, *Garuga pinnata*, *Anogeissus latifolia*, *Bassia latifolia*, and *Terminalia tomentosa*, while the most immune were *Dalbergia latifolia*, *Tamarindus indica*, *Schleichera trijuga*, etc. As the trees affected gradually died down from the tops of the crowns and took two or three years to die down to the ground, those which were felled soon after their crowns were affected gave vigorous coppice shoots—two large trees excepted—while fellings made in the second year gave also fair coppice, but those made in the third year gave weaker shoots. The extent of the damage done may be gauged when it is stated that of Teak alone, which made up about 40 per cent of the forest, 2,782,700 over 9 in. girth and 1,415,500 under that girth were cut out from an area of 152,949 acres, that is, over 27·4 Teak trees per acre (68·5 trees per hectare).

[1] *Indian Forester*, vol. xxix. No. 7, and vol. xxxi. No. 12.

CHAPTER III

LOCALITY

It has already been indicated in the foregoing chapters that, apart from variations in the composition of the soil and climatic changes, certain local conditions may either modify the climate in these particular regions or have some other effect on forest vegetation. The most important of these are: elevation above the sea-level due to mountain regions, proximity to standing or flowing water, winds, aspect, and conformation of the ground. To these we shall now devote our attention.

I have already stated in the last chapter that, at least as regards my own observation within the Tropics, the influence of *elevation* on forest growth, due to the lowering of the mean temperature and rarefaction of the air, does not make itself markedly felt at below 600 metres (approximately 2000 ft.), and probably more, although, on isolated hills, the effect of greater isolation may bring changes more quickly, and, in the neighbourhood of large sheets of water, more slowly.

The decrease of temperature per 100 metres (328 ft.) is approximately 0·58° C.[1] (1·04° Fahr.), and is due to the rarefaction of the air, which has thus less power to absorb heat; it would thus only amount to 3·48° C. (6·26° Fahr.) at 600 metres. All the basal forests situated at elevations up to this altitude, if not more, may be considered as low-country forests.[2]

[1] Schimper, *op. cit.* p. 691.

[2] With the proviso that, as the rainfall increases with increasing elevation, the flora has also a tendency to become more hygrophilous.

In order to see at a glance how the temperature decreases at different altitudes as compared with sea-level, and taking 0·58° C. as the unit of decrease for every 100 metres,[1] I append a statement showing this for every 1000 metres up to 4000 :—[1]

Elevation above the Sea-Level.		Decrease of Temperature.	
Metres.	Feet.	° Centigrade.	° Fahrenheit.
1000	3,280	5·8	10·44
2000	6,560	11·6	20·88
3000	9,840	17·4	31·52
4000	13,120	23·2	41·76

This reduction of temperature according to altitude has the tendency of changing the character of the forests from tropical to subtropical, then to temperate and sub-arctic, but it must be remembered that whereas, in latitudes distant from the equator, the temperature falls with the greater obliquity of the sun's rays and the longer duration of nights during the winter, in the mountains of the Tropics it is due solely to the rarefaction of the atmosphere. This rarefaction has also other effects. As the thinner air is not capable of retaining more than a modicum of heat in its passage, it follows that objects on the earth's surface take it up and thus get heated more quickly, and, in the same way, part with it also more rapidly. Everybody who has lived at high elevations knows how quickly after sunset it becomes intensely cold on a clear evening. A similar difference will also be apparent between the temperature in the sun and that in the shade.[2] In the mountains,

[1] For the convenience of readers not accustomed to the metric system and centigrade thermometer, it may be stated that this works out at about 3·17° Fahr. per 1000 ft. elevation.

[2] During an ascent of Monte Rosa made by the author in 1898, his party sat in comfort on the southern side of the saddle, at about 14,000 feet, while a bolder party of mountaineers tried to tackle the final peak while it was yet in shadow. Owing to the intense cold and frostbite, however, they had soon to come back to the saddle, and to wait for the sun before resuming their ascent.

owing to the same cause, the light is also more intense and evaporation is more rapid. The thin air takes up the moisture quickly and gives it off also more quickly.

Another effect of increased elevation is the corresponding increase in the rainfall. But this only holds up to a certain elevation, above which it again decreases. The zone of maximum rainfall varies, but near the equator, as *e.g.* in Java and Ceylon, it is between 600 and 1500 metres (ab. 2000 to 5000 ft.) at the most.

For purposes of description it may be convenient to divide the forest vegetation into distinct zones, such as *basal* zone, *montane* zone, and *alpine* zone; but in each separate locality the subdivisions made may be more numerous. These zones, although distinct in their component species, gradually shade into each other; and there may be certain species which may stand a considerable range of elevation, as *e.g. Palaquium grande*, *Garcinia echinocarpa*, and *Kurrimia zeylanica* in Ceylon, which range from near sea-level to about 1500 metres (5000 ft.).

It is difficult in a volume of this size to go very much into details in describing the variations of forest floras at various altitudes all over the Tropics; but I shall endeavour to give a general idea of the nature of these changes. Before doing so, however, it is necessary to state that another factor of locality has a powerful influence in determining the character of the flora, and that is the aspect or the direction of the compass which the slopes of the mountains face, as it is from certain directions that the moisture-laden winds come, and it is the slopes receiving their impact on which the greater precipitation of moisture occurs, at any rate up to a certain altitude. Thus we have already seen that in Ceylon the forest on the south-westerly slopes is of a very wet type, with an enormous preponderance of evergreen trees and with dense undergrowth, and, up to a certain elevation, masses of lianas and creepers; while on the other side of the mountains the forest, as soon as it gets out of the zone of moisture-laden air

FIG. 9.—Forest of the wet upper montane zone, Ceylon.

near the coast, is merely a savannah-forest deteriorating into savannah.

On the wet side, then, the Ceylon forests are *basal* forests well up to about 1000 metres (3000 ft.), although some species do not range quite so high. From that elevation up to about 1500 metres (5000 ft.), *i.e.* in the lower *montane* zone, the most characteristic species are the so-called "Red Doons" (*Doona zeylanica* and *D. Gardneri*), while other species belonging to the upper *montane* zone begin to creep in; these are a number of trees belonging to the genera *Eugenia*, *Calophyllum*, *Gordonia*, *Michelia*, with, in the lower tier, *Elaeocarpus*, *Symplocos*, *Meliosma*, and *Vaccinium* (Fig. 9). In the upper *montane* zone the undergrowth differs from that in the lower zone, where it is composed of a great variety of shrubs and climbing plants, among which are several species of the Cane-Palm (*Calamus*), and in more open spaces the larger Hill-Bamboo (*Ochlandra stridula*), or introduced plants such as *Lantana*, while above, the climbers are more scanty and small (e.g. *Medinilla*) and the undergrowth consists either of the smaller Bamboo (*Arundinaria* spp.) or of vast sheets of a great number of species of *Strobilanthes* which flower periodically after a certain cycle of years and die down. It is between 1500 and 2000 metres (roughly 3000 to 6000 ft.) that the greatest development of tree-ferns is to be found, belonging chiefly to the genera *Cyathea* and *Alsophila*, the latter only at the higher altitudes. The sub-arborescent *Angiopteris* of the lower levels also gives way at higher elevations to the very similar *Marattia*. In the more open spaces, where the soil is more swampy, are scattered trees of *Rhododendron arboreum*, while an African montane character is given to the landscape by the appearance of giant *Lobelias*. The highest points of the island do not reach much above 2500 metres (8500 ft.); forests, therefore, reach, under favourable conditions of soil and slope, up to the highest points, but the trees are smaller and the crowns have a twisted and disordered appear-

ance. The upper forests are also characterised by the large masses of *Usnea* lichen, which hang from branches and twigs.

On the drier side of the slopes up to near the top, where the influences of the S.W. monsoon are felt, and where the forest differs little, if at all, from those on the other side of the summit, the basal forests are open savannah-forests with a dense growth of grass between the trees, which are chiefly *Anogeissus latifolia*, *Pterocarpus Marsupium*, *Terminalia Belerica* and *T. Chebula*, *Butea frondosa*, *Sterculia foetida*, with a dwarf form of *Diospyros Melanoxylon* and *Careya arborea*, the last of which ranges up to near 2000 metres (6000 ft.). Farther up most of these species disappear, with the exception of *Careya arborea* and *Terminalia Chebula*, while scattered *Doona zeylanica* takes their place, and, finally, practically nothing is left but scattered *Careya*. But this scarcity of trees, as will be seen later, is largely due to the action of man.

Very similar gradations will be found in the mountain ranges of South India and the Malay Peninsula. Only the Iron-wood (*Mesua ferrea*) seems to have a greater range of elevation; and Teak, which is not indigenous in Ceylon, is found in the basal region, both on the wetter and drier sides of the Ghats, and Burma. Conifers, which are also entirely absent from Ceylon, range into most of the other parts of the Tropics, and in the Indo-Malayan regions, as far as the Philippines and New Guinea, they are represented by the genera *Podocarpus*, *Pinus*, and *Dacrydium*, which are found at various elevations, sometimes not more than 600 ft. and occasionally less; for not only in Asia, as in the Andamans and Upper Burma, but also in tropical Africa and New Zealand certain trees, particularly *Podocarpus*, will be found in valleys and lacustrine swamps, where the soil temperature is low, thus imitating the example of *Pinus montana* in Europe, and of *Quercus incana* in the Sub-Himalayas. In Java, on the wet side of the

island and up to a corresponding elevation, the type of forest is very similar to that of Ceylon, and many of the genera, with the addition of *Podocarpus*, the same; but the mountains soar up to elevations above 3500 metres (12,000 ft.), and the forest vegetation at the greater altitudes is much more stunted with wind-swept crowns, and, except near the summits, much covered with mosses and lichens.

On the drier side, as in Ceylon, a savannah-forest rises above the coast forests, but is composed, on the spurs, of pure *Casuarina montana*, while in the ravines will be found broad-leaved forest, chiefly *Quercus pruinosa*.[1] Among these will also be found genera belonging to more temperate latitudes, such as maples and chestnuts.[2] At above 2800 metres (roughly 9000 ft.), according to Schimper, the forest ceases to exist.

Descriptions of the mountain regions of other islands in the Indian Archipelago show very similar variations; only in Celebes the Screw-pine (*Pandanus*) seems to ascend to and cover the summits of the mountains up to 1560 metres (above 5000 ft.).

In Mauritius the elevation of the mountain ranges does not carry the forests outside of the basal zone, in which the tropical evergreen forest is very similar in character to that of the Indian forests. Among the more important trees are *Calophyllum Inophyllum*, *Canarium Colophania*, *Foetidia mauritiana*, *Eugenia glomerata*, *Diospyros mauritiana*, *Sideroxylon grandiflorum*, *Elaeodendron orientale*, etc.[3]

On the continent of Africa among the mountains and mountain ranges rising to sufficient elevations to show gradations of forest vegetation are the Shiré Highlands and M'lanje, Kilimanjaro, Ruwenzori, Mount Elgon, Mount Kenia, and the Abyssinian Highlands. We possess reports specially written on the subject of the forests of two of them which must serve as types for

[1] Schimper, *op. cit.* p. 726.
[2] *Indian Forester*, vol. xxvi. No. 9.
[3] R. Thompson, *Report on the Forests of Mauritius*, 1880.

the others, viz. Ruwenzori and Mount Kenia,[1] the former in Uganda and the latter in British East Africa.

Of Ruwenzori only the eastern slopes have been explored, and the following transitions were noted:—

Up to 6000 ft. (ab. 1800 metres) the forest flora does not materially differ from that of the lower lands, *i.e.* on the slopes are savannah and savannah-forest with the red-flowered *Erythrina tomentosa* and *Cordia abyssinica* and, in moister places, bananas, while, in the valleys, trees are more abundant and larger, with a *Pseudocedrela* and a *Symphonia* as the most characteristic of them. From 6000 to 9000 ft. (1800 to 2700 metres) the forest gradually shades off from the tropical to the temperate in character. In the lower part of this transition zone Tree-Lobelias (*L. Giberroa*) first appear, as also Hill-Bamboos (*Arundinaria*) and one kind of Tree-heath (*Philippia Stuhlmanii*). This is also the habitat of the Tree-fern (*Cyathea*). The middle portion is characterised by a short, thick-set tree of the natural order of the Proteaceae (*Faurea saligna*); while in the upper portion there is a dense belt of Hill-Bamboo, together with the first appearance of a Conifer (*Podocarpus milanjianus*), which is found in greatest abundance at between 8500 to 9000 ft., but reaches up to 11,000 ft. (3350 metres). Above 9000 ft. the character of the tree flora is temperate; the trees are clad with dense layers of moss and filmy ferns and festoons of the *Usnea* lichen hang from twigs and leaves. The characteristic tree of this zone, up to 12,000 ft. (3660 metres), is the true Tree-heath represented by two species (*Erica arborea* and *E. Mannii*), while the *Podocarpus*, as stated above, does not reach quite so high. In this zone three different kinds of Tree-Lobelias succeed each other and range up to the foot of the glaciers, while Tree-Senecios, the "giant groundsel" of Johnston,[2]

[1] *Report on a Botanical Mission through the Forests of Buddu*, etc., by M. T. Dawe, 1906, and *Report on the Forests of Kenia*, by D. E. Hutchins, 1907.

[2] Sir Harry Johnston, *The Uganda Protectorate*, 1902.

range from 9000 to 13,000 ft. (2700 to nearly 4000 metres).

On Mount Kenia, which like Ruwenzori lies under the equator, the forests on the south-east and western slopes have been explored. Mr. Hutchins describes those between 6000 and 9000 ft. (1800 to 2700 metres) as practically the same as the Yellow-wood (*Podocarpus*) forests of South Africa, with the addition of Juniper (*J. procera*). In the Kenia forests, especially on the south-eastern slopes, the forest is however finer than those of the Cape Colony, the trees are closer and taller, and the shade is dense enough to keep off undergrowth. On the western side, the rainfall being only about two-thirds of that on the eastern, the forest is more open and more interspersed by glades; it also begins at 1000 ft. (300 metres) higher than on the wetter side, while above the tree-forest there is, on the eastern side, a dense and continuous belt of *Arundinaria* bamboo stretching up to the base of the upper cliffs, which is absent on the western side, or found only in damp ravines or in patches. The variation in rainfall also causes a certain change in the composition of the forest. On the south-east slopes the principal species is *Podocarpus milanjianus*, with a large *Cinnamomum*, an *Albizzia*, *Olea laurifolia*, *Ochna* sp., and several undetermined trees; while on the western side the Juniper takes the lead associated with the above-named *Podocarpus* and another of the same genus (*P. elongatus*), with *Olea laurifolia*, which is more abundant on this side than the other, and other undetermined trees. Rubber vines (*Landolphia Kirkii*) are found in small numbers in the warmest parts of the south-eastern forests.

These descriptions must suffice for tropical Africa. It is only necessary to state that the Juniper, which extends into the Abyssinian highlands, is replaced in the southern portion of this zone by the "M'lanje cedar" (*Callitris Whytei*). In tropical America[1] certain

[1] Schimper, *op. cit.* pp. 743-748.

variations of types of forest at various elevations can be noted. In Mexico the basal region extends to about 1000 metres (3000 ft.), and consists of tropical rain-forest to the south, while farther north the moist ravines alone have this type of forest. On the spurs is an open thorn-forest of Cactaceae, Acacias, and Tree-lilies. From 1000 to 2000 metres (3000 to 6000 ft.) the montane region has a heavy rain-forest consisting largely of evergreen oaks in the lower portion, and deciduous oaks higher up. Above 2000 metres the coniferous forest begins, and this belt, in the higher parts, gradually gives way to scattered deciduous oaks, limes, and alders. The upper parts of the elevated peaks of Orizaba and Popocatepetl are covered by steppe and shrub, and finally end in desert.

The mountain regions of equatorial South America, in Ecuador, New Grenada, and Venezuela, show similar gradation from the rain-forest in the basal and montane belts and dwarf trees passing into steppe, here called *paramos*. The temperate belt is characterised by being the home of most Cinchonas. Farther south, the rainfall on the western slopes being scanty, these have the appearance of deserts, and have only a very scanty vegetation. Such an alpine desert is called a *puna*. As regards the littoral mountain ranges of Brazil, which do not rise above 2700 metres (ab. 8900 ft.), the basal tropical forest is followed by the montane zone, in which the twiners are few and thin and epiphytes scarce; and in the upper portions of this belt will often be found a pure forest of *Araucaria braziliana*, above which there is a similar formation to the *campos* described before.

We have already seen in foregoing descriptions of forests that their character in the *vicinity of the sea or other sheets of water*, or in damp ravines, is affected not only by the saturation or infiltration of water into the soil, but by the greater relative humidity of the atmosphere; and that, where the latter is great, the forests are generally evergreen, as, for example, over the greater part of the

low country of Ceylon and Java. It has also been stated that on the central African plateau and in parts of South America the dense forest is confined to the watercourses, the higher ground being covered by steppe or savannah or open forest. There are some other peculiarities of forest vegetation caused by the presence of water which deserve some special mention.

On the sea-shores of the Tropics, in regions where the rainfall is also abundant, the estuaries of rivers, backwaters, and lagoons, which are covered with water at high tide and are left exposed to the air during low tide, there is to be found a type of forest known as "Mangrove Swamps," which has some peculiar characteristics. Most of the trees require a certain amount of fresh water in order to be able to live, but some may live in undiluted sea-water, as *e.g. Rhizophora mucronata.*[1] Many of the trees growing in the black mud of these swamps support themselves by stilt-like roots which spring out of the stems and, even in the case of the tree mentioned above, from the branches. They are thus able to support themselves in the liquid mud from which they spring. In order that the roots may be supplied with the oxygen which they require, they give out curious negatively geotropic branch roots, known as pneumatophores, which emerge from the mud in the shape of pointed cones, or "knee-roots," provided with lenticels, stomata, or part excortication, in order to take up the oxygen at low tide. The foliage of these trees is generally thick and fleshy, and the fruit starts germinating before it falls from the tree. In the case of the true Mangroves (*Rhizophora*, *Bruguiera*, and *Ceriops*) the radicle goes on lengthening until it is sometimes the length of the arm. As it is more or less pointed, and the lower end is heavier than the plumule end, the seedling remains upright when it detaches itself from the tree and fixes itself vertically into the soft mud, into which it at once proceeds to send out roots to establish itself. The most important natural order in

[1] Schimper, *op. cit.* p. 396.

these mangrove woods is that of the Rhizophoraceae, represented in Asia, the Malay Archipelago, and Australia by the genera mentioned above, and in America and West Africa by Rhizophora (*R. Mangle*). The *Rhizophora* is the genus which can live in the water least diluted by fresh water, while farther up the estuaries, where the influence of the tide is less felt, the other genera gradually come in, associated with others belonging to other natural orders, such as *Lumnitzera* (Combretaceae), *Carapa* (Meliaceae), *Sonneratia* (Lythraceae), *Aegiceras* (Myrsineae), *Avicennia* (Verbenaceae), and *Nipa* (*Palmae*) in the eastern seas, and *Laguncularia* (Combretaceae) and *Avicennia* in the seas bathing the shores of West Africa and East Tropical America. The *Rhizophora* is commercially important, chiefly on account of the tannin obtained from the bark.

In the more shallow portions of the swamps other species come in. In Ceylon and elsewhere, for example, great stretches get filled with a large "flowering" fern (*Acrostichum aureum*) or with Screw-pine (*Pandanus*) (Fig. 10), the stilt roots of which adapt it well to the unstable soil in which it stands.

Close behind the mangrove brake, but generally, though not always, above the high-water mark, comes another type of forests with trees, the fruit of many of which is adapted to transport by water. The most interesting to foresters by the eastern seas are the fruits of *Heritiera*, one of which (*H. Fomes*) yields the valuable elastic Sundri-wood of the Sunderbunds in the Gangetic delta. Its fruit, containing an air-chamber, has a hard polished epicarp, which is boat-shaped and provided with a sharp keel, which not only helps it, in navigating various currents, from being rolled over and bruised, but which cuts into muddy bottoms and helps as an anchor. Another economic tree of this belt is the Coconut (*Cocos nucifera*), the fruit of which is surrounded by a thick fibrous envelope. Among others may be mentioned *Hibiscus tiliaceus*, *Terminalia Catappa*, *Sonneratia* spp., *Barringtonia speciosa*,

Calophyllum Inophyllum, *Cerbera Odollam*, with an undergrowth of *Pandanus*, *Acanthus ilicifolius*, and climbers, such as *Derris scandens*, *D. sinuata*, *Acanthus volubilis*, etc.[1]

FIG. 10.—Screw-pine (*Pandanus*) showing stilt-roots, Ceylon.

Apart from the direct influence of water in the soil in the neighbourhood of large sheets of water, whether the sea or lakes, such as Lake Victoria in Central Africa,

[1] B. Ribbentrop, *Forestry in British India*, 1900.

or large rivers such as the Nile, the Congo, or the Amazon, the atmosphere takes up from them a large amount of water by evaporation, this amount varying from a daily mean, for the year, from about 3 to 10 millimetres, according to whether the locality is in a heavy rainfall zone or not. This saturation of the atmosphere, where it can be effected, has a distinct influence on the general character of the forest, which may have the appearance of a rain-forest, with a large preponderance of evergreen trees, even where the rainfall is considerably below 1900 millimetres (75 inches). My own experience ranges only from the coast forests of Ceylon, which are mostly evergreen, with a rainfall of down to 875 mm. (35 inches), to the evergreen scrub-forests of Erkoweit in the range of hills fringing the west coast of the Red Sea. The former I have already described. In many places they come right down to the sea-beach, where the trees are twisted and stunted by the winds, and while in the northern part of the island, where there are no mountain ranges to speak of, they extend from the east to the west coast with a small interruption made by thorn-forest caused by a pan of heavy black clay or "cotton-soil," farther south, on the drier east coast, the evergreen belt stretches up to about 50 miles from the coast.

The Erkoweit plateau, situated at about 1000 metres (above 3000 feet) above the sea-port of Suakin, is another instance of how a variety of factors may combine and constitute a certain class of forest. The majority of the neighbouring hills are composed of the red Nubian sandstone, which absorbs both heat and moisture without retaining the moisture. The moisture-laden winds from the sea are therefore insufficient to clothe these slopes with more than sub-desert flora, such as fleshy and thorny plants not unlike those found in Mexico, viz.: thorny Euphorbias, occasional stunted Acacias (*A. etbaica*), fleshy Zygophyllaceae, Ficoideae, Asclepiadeae, Crassulaceae, Aloes, and Tree-lilies (*Dracaena*), and thorny, stunted Acanthaceae. The outcrop of granite

at Erkoweit, which enables moisture in the soil to be retained, causes arborescent growth to appear, among which, in order to avoid heavy transpiration, the evergreens are very apparent. The principal representatives are *Diospyros mespiliformis*, *Olea europaea* var. *nubica*, *Euclea Kellau*, *Carissa edulis*, *Nuxia dentata*, *Dodonea viscosa*, *Ximenia americana*, *Rhus abyssinica*, *R. viscosa*, *Gymnosporia luteola*, *G. montana*, and *Ficus glumosa*, while among the undergrowth will be found Labiatae, Umbelliferae (*Pimpinella*), various Compositae, *Plumbago zeylanica*, ground orchids (*Bonatea*), lilies, and, in cool nooks, various delicate ferns (*Adiantum*, *Asplenium*, and *Cheilanthes*). Climbers are few, the most important being the "Traveller's joy" (*Clematis Thunbergii*) and a vine (*Vitis concinna*).

The number of species of trees which are able to have their roots covered by fresh water, even when it is well-aired, flowing water, is comparatively limited, and areas subjected to periodic floods are often covered by a type of forest very different from that found on the adjoining higher ground. For example, both on the Nile (as far south as about 12° N. lat.) and on the Indus pure forests of *Acacia arabica* cover the low banks, which are perhaps one to two metres under water during flood time. At other places Tamarisk (*Tamariscus articulatus* and *T. gallica*) takes the place of the Acacia. Farther south on the Nile *Acacia Suma* and *Acacia verugera* replace the *A. arabica*. In the periodically inundated littoral forests on the western shores of Lake Victoria a variety of the same *Podocarpus* which forms forests on the slopes of Ruwenzori (*P. milanjianus* var. *arborescens*) has established itself, and, as has been mentioned already, another species of the same follows the same example in the Andamans. In the wet zone of Ceylon one of the Dipterocarps (*Vatica Roxburghiana*) will be found growing in places, with not too swift a current, which are inundated each year. The fruit gets ripe just about

the time of the highest flood and begins pushing its radicle through the spongy pericarp. When the fruit has dropped into the water its centre of gravity is so contrived that the radicle lies underneath, and when the pericarp gets water-logged and the fruit sinks to the oozy bottom, the root can, at once, proceed to make itself firm in the soil. With this as well as with most water-borne fruits a sluggish current is necessary for proper regeneration and for dispersion of the seed, and too great a clearing of trees may at once stimulate a current which will bear the fruit away. An allied tree of the above (*V. obscura*) will be found in the tracts liable to inundation on the eastern side of the island. In the river swamps of Burma the forest will be a mixed one of evergreens and leaf-shedders, such as *Anogeissus acuminata*, *Mangifera longipes*, *Xanthophyllum glaucum*, with several species of *Eugenia*, *Elaeocarpus*, *Symplocos*, also *Cassia Fistula*.[1] Here, in order to resist excessive transpiration, the leaf-shedders are said to be leafless during the rainy season.[2] In places, inundated lands may degenerate into savannah-forests or savannahs, and they may be only grassland. But the last-named condition is largely due to the fires which, in the dry season, sweep over these plains. The swamps of the Upper Nile, generally known as the Sudd region, are an example of this, for I have found a number of trees such as *Crataeva Roxburghii*, *Trichilia emetica*, *Kigelia aethiopica*, *Acacia Suma*, *Euphorbia Candelabrum*, *Borassus flabellifer*, etc., trying to gain a precarious footing in these swamps, together with the curious pith-tree or Ambatch (*Herminiera Elaphroxylon*), which, however, was more constantly under water. Several of the trees and shrubs were found to grow on the summits of termite nests.

In tropical South America the tree which is at present of the greatest economic importance, the Para Rubber (*Hevea braziliensis*), is to be found in situations

[1] B. Ribbentrop, *op. cit.* p. 30. [2] Schimper, *op. cit.* p. 385.

which are liable to shallow inundations. Similarly, the "Bullet-tree" (*Mimusops Balata*) of British Guiana, where it is found between the Berbice, Demerara, and Essequibo rivers, and also in Dutch and French Guiana, parts of Brazil, the Antilles, and the Bahamas, and which yields the substance, nearly allied to gutta-percha, known as "Balata," grows on alluvial flats only a few feet above the river banks.

Although on the banks of rivers it is common to see trees growing which are also found away from running water, in perhaps wetter rain-zones than that of the particular locality where they line the banks, it is only a very limited number that can exist near stagnant water, whose rise and fall is due to local rainfall collected in depressions and to subsequent evaporation.

In the northern half of Ceylon the Sinhalese, before and after the beginning of the Christian era, established a very complete system of irrigation by damming water-courses, and thus forming storage tanks for the water required for their crops. In the eighth century A.D. they began to be driven back by the devastating armies of the Tamils from the Indian mainland. Their cities were sacked, and the tanks, deprived of necessary repairs and upkeep, were soon breached and forests invaded their beds. Under the British Government cultivation was again brought back to these regions, and many of the tanks have been repaired and filled with water. The result has been, as regards such of the trees as were not removed beforehand, that most of them died in the first year of inundation. A few, such as *Terminalia glabra* which is found growing along rivers and watercourses, struggled for a few years by throwing out aerial roots (Fig. 11), but they also eventually succumbed if immersed too deeply, or only survived quite on the edge of the tanks. The species which stood periodic inundations best were *Barringtonia acutangula*, *Vitex Leucoxylon*, *Bauhinia racemosa*, and *Feronia elephantum*, which elsewhere are indications

of wet pans in the soil. In Africa, *Bauhinia reticulata* takes the place of its Asiatic relative, together with *Maba abyssinica*, *Antidesma venosum*, *Turraea nilotica*,

FIG. 11.—*Terminalia glabra*. Note the adventitious roots formed on the buttresses while they were submerged.

Acacia Seyal var. *Fistula*, which sometimes forms pure woods, *Cordia Rothii*, etc. Although my own experience within the Tropics does not extend elsewhere, each locality will have its own tree flora adapted

to similar circumstances, and it becomes necessary for the forester to study his own forest flora, and not to try to introduce into such localities such species as are unable to struggle against stagnant humidity of the soil.

We have already seen that the effect of some *winds* in the Tropics is to bring rain to the country, and that this is particularly the case with trade-winds which herald the break of the rainy season, and during the whole of that season bring a more or less constant supply of moisture-laden clouds to drench the parched country. Except near the equator, where the rainy season is more regularly distributed throughout the year, there are at other times of the year dry winds, which have the opposite effect, for they increase evaporation without bringing any adequate rain to replace what is taken away. During that time, therefore, only such trees as are provided with the means to resist such transpiration can survive. The most common method of resisting the drying influence of the air is leaf-shedding, and it is for this reason that forests will be leafless during the hot weather, that is, during the rainless period, and not through the winter as in temperate and arctic zones, where it is the frost which has a desiccating influence.

The mechanical effect of the wind on trees is felt especially in exposed places, as on a sea-shore, where the tree vegetation may often be seen to be stunted and cut away slanting upwards from the water's edge, the hinder ranks of trees gradually increasing in height behind the shelter of those bearing the first impact of the winds. Solitary trees in such localities are frequently seen bent down with their crowns almost parallel with the ground. On exposed mountain ridges twisted crowns and the twisted fibre of the timber will constantly testify to the action of the wind. As the violence of the wind is much greater at some distance above the ground than near the surface, tall trees are more liable to have twisted fibre than short ones, or at least they will grow

unevenly, and the wood will form more rapidly on the sheltered side than on that exposed to the wind. Sudden hurricanes, which are liable to come on in many places in the Tropics, are liable to do more actual damage than constant winds, and will take advantage of any gap in a forest to cause havoc among the trees by throwing them down or breaking them; and, where they are bound to other trees by great liana ropes, they will in their fall drag others with them, which in their turn will tear others down. In such places it is desirable to have as complete a leaf-canopy as possible, and that the trees be mostly shade enduring, in order that their seedlings may make a start under their shelter. The following remarks about the evergreen forests of Mauritius, which are liable to visits of hurricanes, will be of interest here :—[1]

"By the compactness of their growth and a certain special development they bid defiance to the hurricanes which now and then visit the island; and though individual trees, composing the mass of vegetation, may, owing to the little hold they have upon the soil, be overturned by the mere weight of a man leaning against them, yet owing to the stillness of the air, which at all times prevails within the forests and is so maintained by the impenetrable mass, the most fragile twig is as safe from injury from strong and violent winds, as it would be, were it growing in a well-constructed hothouse."

The wind has also to be considered as a factor in the pollination of certain plants. As regards forest trees this is particularly noticeable in the dispersion of pollen of the Conifers and Bamboos, the pollen of which is carried by the wind. Certain trees also provide themselves with wings for their fruit or seed which thus get distributed by the wind. Many of the Dipterocarps, as the name of their order indicates, have wings attached to their fruit, e.g. *Dipterocarpus*, *Hopea*; most species of *Shorea* and *Doona* have two or more wings, sometimes several inches long, formed by the

[1] R. Thompson, *Report on the Forests of Mauritius*, 1880.

accrescent calyx lobes, giving the fruit the appearance of a shuttlecock. These wings help in the dispersal of the fruit by the wind, and also act as parachutes to prevent the delicate radicle, which often protrudes from the fruit before it becomes detached, from being injured by its fall on the ground. Other trees provided with very similar appendages for their fruit are *Gyrocarpus*, (Combretaceae), *Lophira* (Ochnaceae), and *Monotes* (Tiliaceae ?), while a large number of Combretaceae have two to five costal wings on their fruit. Among the Leguminosae the *Dalbergia* has light, indehiscent legumes which get blown away to some distance, while the *Pterocarpus* has its larger one seeded legume disc-shaped and edged with a continuous wing. In *Daniellia* and *Cyanothyrsus* the seed, which is attached by a filiform process to a dehiscent legume, carries away, in its fall, portion of this legume, which is thin and membranous and acts as disperser and parachute. Among other winged fruits may be mentioned that of *Securidaca* (Polygalaceae), *Berrya* (Tiliaceae), and the hairy umbrella-like parachutes of the Compositae and other appendages of several shrubs and climbers. In other trees it is not the fruit but the seed which is provided with winged or silky appendages for its dispersal; such are several of the Malvaceae (*Bombax*, *Eriodendron*, and *Gossypium*), *Pterospermum* (Sterculiaceae), many of the Meliaceae (*Swietenia*, *Chloroxylon*, *Khaya*, *Chickrassia*, *Azadirachta*, *Cedrela*, etc.), several Apocynaceae (*Funtumia*, *Adenium*, *Holarrhena*, *Alstonia*, etc.), the Asclepiadeae, most Bignoniaceae (*Stereospermum*, *Millingtonia*, *Oroxylum*, etc.), and the Salicineae. As many of the genera mentioned have great economic importance the study of the dispersal of their seed is of much interest to the forester.

The effect of winds on loose sandy soils or, in dry countries especially, on soft sandstone formations is exemplified by the formation of dunes and sand-drifts. The term "dune" is more particularly applied to the

sandy ridges formed by the driving action of the wind on sand which has been cast up by the sea. But very similar formations will also be formed inland where, the rainfall being small, or other circumstances intervening, no vegetation springs up and the sand is driven forward and encroaches on other land. The fixation of the dunes of Gascony is now historic; but, in tropical countries with a small rainfall, the problem of stopping the encroachment of these sandy hosts is much more difficult to solve. In the province of Dongola, in the Sudan, for example, the dry winds, coming from the north-east across the desert, have brought waves of sand which cover up cultivable land, palm-groves, and woods. In Kordofan the dunes, locally known under the name of "goz" (or hill), have advanced and covered up the country until they reached a region of sufficient rainfall, where they got fixed by vegetation in the shape of open thorn-forest, the characteristic tree of which, as we have seen, is the *Acacia Verek*. In moister climates, especially near the sea, the dunes have less chance of encroaching on the land behind them to any large extent, as they soon get clothed by herbaceous and shrubby growth which fixes them. Such dunes may be found, for example, on the coasts of Java and Ceylon, where they often do not exceed one or two ridges.

As regards *aspect*, which may be defined as the point of the compass which any sloping land faces, it is of importance chiefly as regards the direction from which moisture-laden winds come. Within the Tropics, the sun swinging now to the north and now to the south, at midday, thus greatly nullifies the effects that northern and southern aspects have in regions more distant from the equator. Also with the high angle to which it swiftly ascends early in the day, even westerly slopes, unless they are very steep, are soon bathed in sunlight, while the easterly slopes remain so until well on in the afternoon. Nevertheless, in the Tropics of the northern hemisphere, the sun being to

the north during the hottest months, the northerly aspects, especially the north-westerly, will be the hottest, and in the southern Tropics the south-westerly.

In localities where frosts occur it is on easterly aspects that plants are most liable to suffer from frost-bite, owing to the sudden heating by the sun's rays immediately after sunrise. This is particularly the case at high elevations, where the atmosphere, being thin, lets the full force of the rays strike the plants.

There is not very much to add about the effect of *configuration of the ground* on forest vegetation. The angle of the slope affects the drainage of the country, and it is clear that where this is too slight the flow of the water is liable to be retarded unless the soil is of sufficient porosity and depth to allow it to sink. Where it is not so constituted it will have a tendency to become marshy, and only swamp forest can grow on it, or even only reeds and sedges, such as the Papyrus of Africa. On the other hand, steep slopes are quickly drained, especially where vegetation is scanty. On steep slopes trees must either have a strong root-apparatus or they must be able to grow in a sufficiently dense mass to resist atmospheric disturbances, landslips, etc. The soil is generally less deep on the slopes than in the valleys, and this, combined with the quicker drainage, makes the vegetation assume a more open character. Fires therefore are more to be feared on them, and for this reason, in many places, as has already been seen in the case of the central African plateau, the forest is more or less confined to the low grounds. Similar changes may be observed in the "campos" of South America and elsewhere.

CHAPTER IV

PLANT AND ANIMAL ALLIES AND ENEMIES (EXCLUDING MAN AND DOMESTIC ANIMALS)

In dealing with the subject of vegetable allies and enemies of forest growth it is sometimes difficult, in our present stage of knowledge, to discriminate as to whether the vegetable forms under consideration are an encouragement to the kind of forest required by the owner or whether they are a hindrance. It may depend, for example, on whether these plant forms have themselves, or acquire, a sufficient economic importance to make their presence desirable. Take Bamboos for example. It may be most undesirable to see them appearing in a forest filling up gaps which can be filled more advantageously by seedlings of more valuable trees. Thus, in parts of Burma they invade the forests and drive out Teak and other valuable species. But a demand for that particular kind of bamboo may arise, which will be as profitable to the owner as a mixed forest of Teak, and which, maybe, gives the soil the shelter which it requires. Such is the case with some other gregarious plants which are classed as pests, and, no doubt, are pests to those who wish to cultivate the soil or who wish to get a quick regeneration in the forests. Among these, one of the most important is the Lantana. *Lantana aculeata* and *L. mixta*, straggling shrubs, natives of tropical America and introduced into other parts of the Tropics as ornamental plants, have spread in the moist and wet zones, especially the latter, up to above 1000 metres (3280 feet), sometimes

covering extensive areas of country. But where they are most abundant is where indiscriminate fellings have been made, such as those preceding temporary or shifting cultivation, *i.e.* a method of cultivation very prevalent in the Tropics and consisting in raising crops on forest land manured by the ashes of the trees that stood on them. As this cultivation is carried on only for a few years until large yields are no longer obtainable, the blank spaces are abandoned and fresh clearings made. Nature then uses the most ready means for covering up the soil, and Lantana, whose edible seeds are largely dispersed by birds and other animals, has stepped in and covered the soil until shade-enduring plants, springing up under its cover, push their heads through and proceed to form tree cover. Another plant following a similar rôle is the Mexican sunflower (*Tithonia diversifolia*), and in other places where the Lantana has not arrived in time and which are no longer suitable for its reception, the sun-loving fern, *Gleichenia linearis*, and bamboo such as *Ochlandra stridula*, or, on very exposed faces, the surface of which has been washed off by tropical downpours, scanty shrubs and undershrubs such as *Hedyotis* and various Composites. In the montane zones the Arundinaria bamboo also often covers large tracts and renders regeneration of trees difficult; and in Asia a widely represented genus, that of *Strobilanthes*, forms dense thickets, which keep all the light from the ground and thus retard natural regeneration, especially in places where the seed being light it cannot always reach the soil. In Ceylon, where there is an extraordinary abundance of these plants, the fruits or seeds of forest trees are mostly spherical and heavy and belong to shade-enduring species which are thus able to germinate and to maintain themselves under cover until the periodic flowering and seeding of the *Strobilanthes*, an event which occurs every 4-12 years, when the latter dies down and tree seedlings can shoot up until they are again caught up and have to wait another period under cover. This, of course, means

a very slow period of regeneration, and the dense undergrowth, from this point of view, may be considered as an enemy. An allied genus, *Stenosiphonium*, performs a similar office in the dry low country, while, in places, where shifting cultivation has taken place, the whole area may be invaded by a dense mass of grass such as *Imperata arundinacea*, which is very slow in giving way to forest. In other places, both in dry and wet zones, a secondary forest springs up, composed, in the drier zones, mostly of thorny and small trees and shrubs, and, in the wet zones, of evergreens, frequently thorny too, which protect the soil and improve it for the gradual reintroduction of tree forest. It is an interesting fact that Nature, in its last desperate attempt to protect the soil, arms a large number of the plants she uses for that protection with defensive weapons which ward off the attacks of most animals excepting, perhaps, man.

Climbing plants may generally be considered as enemies of the forest, for they use the stems and branches of trees in order to reach the light, and, when they have done that, they establish themselves among the crowns and keep light and air from them. The most deadly are the twiners which constrict the plants which help them up and prevent their regular growth. It has already been mentioned that lianas, in passing from one crown to another, bind trees together, and that if one of these falls or is felled it is liable in its fall to pull others down. Of course, among these climbers there are some which, although they are unfriendly to their hosts, have an intrinsic economic value of their own and deserve encouragement for that purpose. Among them the most noteworthy are those yielding rubber, such as certain species of *Landolphia*, *Carpodinus*, and *Clitandra*, or certain Cane-Palms (*Calamus*).

Climbing plants obtain their greatest development in the wet zone or in damp localities such as banks of rivers (Fig. 12), and the damage done to trees is not only due to woody climbers, but also to herbaceous or

semi-herbaceous ones, such as many of the Convolvulaceae and Cucurbitaceae which cover the crowns of trees with a dense matted mass which excludes all light and air. One of the most important forest operations in such places, therefore, is systematic cutting bark of climbers in order to preserve the life of the trees and to encourage the springing up of seedlings.

Certain epiphytes, especially those of the genus *Ficus*, have a similar effect to that of twiners. Many figs germinate in the axils of branches, from where

FIG. 12.—Climbers in riverside forest, Blue Nile.

they send roots along the bole down to the ground (Fig. 13). These roots or their branches cross and join together and gradually enclose the tree, which they ultimately kill. As the axils of palm-leaves retain moisture for a long time it is most common, where they grow, to find them apparently growing out of fig trees, whereas really they are the hosts, the bases of which have been concealed within the folds of the aerial roots of the figs. Among those of economic importance may be mentioned the true India-rubber tree (*Ficus elastica*) which is found in Assam and Burma. It germinates on the tallest forest trees and sends down its aerial roots to

the soil, after which it makes quick progress, and has ultimately the appearance of a tall forest tree, but its host has disappeared.

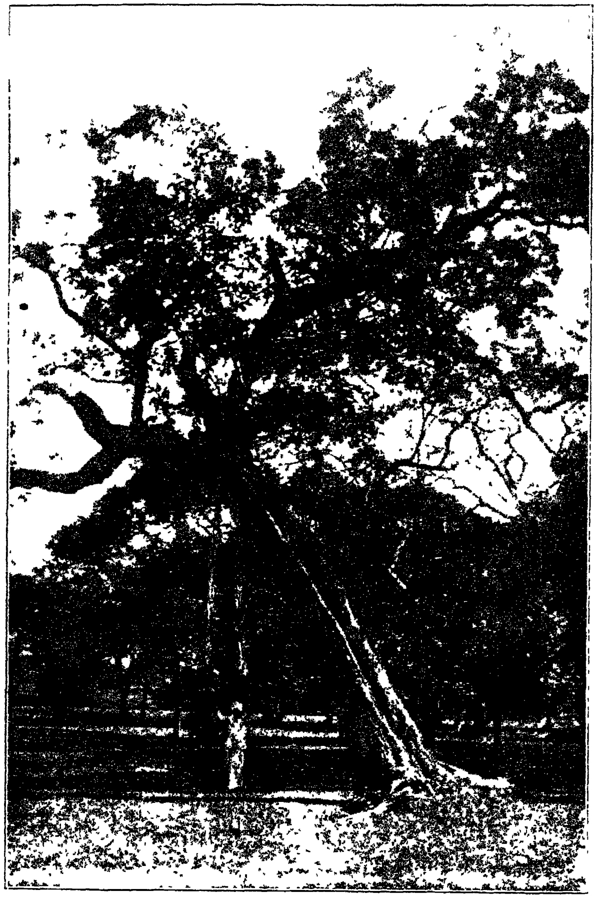


FIG. 13.—Epiphytic fig or *Mimusops hexandra*, Ceylon.

Mention has already been made of the lichens which make their appearance on branches, twigs, and leaves, especially in the wet montane zone. These have the effect of excluding air and may be classed among the enemies of the forest, although they may exercise some

beneficial functions which have not been appreciated yet.

The vegetable parasites may be broadly divided into fungoid and phanerogamous parasites. On the subject of the former, volumes could be written by specialists, and even had I the requisite knowledge, I have not the space here to go into details. They may be subdivided into root-fungi and stem- and branch-fungi, and to them may be added saprophytic fungi which live on perishing vegetable matter and do not attack healthy trees.

The root-fungi attack the roots of trees and they pass from one tree to another often by root contact. Such is, for example, what is called "Spike" in the Sandal tree, which is itself a parasite, and destroys the haustoria, through which the latter obtains nourishment from other plants. An example of *Fomes Pappianus* destroying large numbers of *Acacia arabica* in India is cited in the *Indian Forester*.[1] Here it is presumed that although the spores entered through wounds above ground, the infection from tree to tree has been communicated by root contact. The "leaf disease" of Ceylon, which destroyed the coffee plantations, was a fungus (*Hemileia vastatrix*) which spread from the forests. In the same way, the "Cacao-canker" is also due to a fungus spreading from the forests. Similarly, dry-rot in trees is due to fungoid attacks. As several of these fungi select special species for their attacks, one of the greatest safeguards for the forest against the spread of fungoid diseases from infected centres is to have a mixed forest, *i.e.* a forest composed of a variety of species. In pure forests the disease, finding congenial hosts on all sides, is much more liable to spread, and energetic measures may have to be taken to prevent damage and perhaps destruction of the crop. Among the remedies may be cited the removal and burning of diseased twigs, branches, or even whole trees, the smoothing and tarring of wounds, the destruction of

[1] E. E. Fernandez in *Indian Forester*, vol. xxix. No. 6.

sporophores, or the digging of trenches to prevent the underground spread of the pest. Forest operations should also be carried out with care so as not to injure the trees which are left standing by felling, and thus not to provide ready means of ingress to the spores of injurious fungi. It may be mentioned here, however, that fungi are not all injurious. Many saprophytic fungi carry on a useful mission in destroying dead matter, the superabundance of which would destroy plant life. Some plants even, such as *e.g.* the *Rhododendron*, cannot exist without the existence of certain fungi in the soil, and presence of bacteria on roots of leguminous plants has been proved to be of distinct benefit in improving the soil.

Among the phanerogamous parasites the natural orders of the Loranthaceae and Santalaceae are perhaps the most important to foresters. The former family, to which the mistletoe of Europe belongs, is found also in Asia, Africa, and Australia, and is represented by the genera *Loranthus* and *Viscum*, of which the former is the more widely or abundantly distributed. The seeds are distributed chiefly by a bird (*Dicaeum*). The glutinous seeds remain attached to branches of trees, into the cambium of which they send their roots, and from which they derive their nourishment, or, at least, partly so. Great damage is done to forests in which these parasites establish themselves, and the best remedy is to cut them out ruthlessly. In the arid zone of the Egyptian Sudan, however, the twigs of *Loranthus Acaciae* are greatly prized by the Arabs for camel-fodder, and, in such circumstances, the sparing of the parasite may be considered.

Of the Santalaceae the Sandal-wood tree (*Santalum album*) is the most important, as it yields a wood of great value. It is said to become a root-parasite only after living free for some time, and to attach itself by preference to such trees or shrubs as *Cassia auriculata*, *Lantana*, and *Casuarina*. Among other parasites may be mentioned rootless climbers, such as

dodder (*Cuscuta*), which, on becoming a parasite, allows its roots to perish in the ground whence it originated, and, with similar habits, *Cassytha*, the former belonging to the natural order of the Convolvulaceae, and the latter to the Lauraceae. There are also the Orobanchaceae, such as *Cistanche lutea*, which shows a preference for the roots of *Capparis aphylla*, but is also found on those of *Acacia*, *Zizyphus*, etc. ; also the handsome root-parasite of Malaya, the *Rafflesia*, and in montane regions of the Tropics *Balanophora*.

In the *fertilisation of flowers* and in the distribution of seeds animals are an important factor in the formation and maintenance of forests. Insects and birds are largely responsible for pollination, especially the former, and the character of the vegetation may easily vary with the presence or absence of pollinating insects or birds.

Among the insects the Lepidoptera, Diptera, and Hymenoptera are those which carry out these functions, while among the tropical birds may be mentioned the humming-birds, sun-birds, and honey-birds. So dependent are certain trees on pollination by specific kind of animals that they adapt their flowers to forms or colours which will attract them and no others. Thus plants fertilised by nocturnal insects will have their flowers opening by night, white in colour, and often sweet-scented. Others will shape the tube of the corolla or the nectary in such a manner as to admit the proboscis of certain moths or the beaks of certain birds. It is true that certain noxious plants are also pollinated by animals, *e.g.* the *Loranthus longiflorus* in India has been found to be pollinated by the honey-bird (*Arachnectra asiatica*),[1] but nevertheless the amount of good done far exceeds the evil.

In the *distribution of seed* birds and mammals also play an important part. In order to effect this a large number of seeds are surrounded by an edible envelope. We have already seen that the glutinous fruit of

[1] *Indian Forester*, vol. xxv. No. 12.

Loranthus is propagated through the agency of a small bird (*Dicaeum*) [1] which, after bursting the outer envelope with its beak, swallows the pulpy fruit whole for the sake of the pulp, and voids it on to a branch, where it attaches itself by the remains of the glutinous pulp sticking to it. This is an example of a noxious bird, and others will thus transport small seeds, such as those of different species of *Ficus*, and deposit them on branches where the young epiphyte will germinate as described above in this chapter. Deer, antelopes, and elephants take up a large number of edible fruit, and, as regards the former, it is no uncommon sight to come in the forest on heaps of hard kernels which have been rejected after the outer pulp has been eaten. As examples of such may be quoted, for India, *Terminalia Belerica*, *Zizyphus Jujuba*, *Phyllanthus Emblica*, etc., and for Africa, *Balanites aegyptiaca*, *Zizyphus mucronata*, *Ximenia americana*, and *Diospyros mespiliformis*. The Asiatic elephant is particularly fond of the *Terminalia Belerica*, *Feronia elephantum*, and *Phyllanthus Emblica*, the seeds of which are voided after being deprived of their pulp, while the African elephant has a marked preference for *Balanites aegyptiaca*. Jackals eat the pulpy fruit of *Zizyphus Jujuba*, and void the hard kernel enclosing the seed. To a certain extent cattle, and more especially goats and sheep, propagate seed. It is stated that in the Babul (*Acacia arabica*) forests of the Bombay Presidency the pods of the trees are greedily eaten by the goats, which either reject the seeds after chewing or void them.

Certain plants provide their fruit with hooked bristles or thorn-like appendages, which get attached to the fur of animals and thus get distributed; but this is rare in the case of forest trees, although some have provided their edible fruit with spines to prevent them being attacked.

Several tropical trees, in order to be protected from

[1] *Indian Forester*, vol. xxv. No. 12.

the attacks of injurious insects or other animals, invite the presence of warlike ants by providing them not only with dwellings in the shape of hollow stipular thorns (as with *Acacia Seyal* var. *Fistula* of Africa and *A. cornigera* of America), or hollow internodes (such as *Humboldtia*, *Triplaris*, etc.), or hollow shoots (such as *Cecropia*), but also with food. In the case of the last-named tree, it is with other ants—the leaf-cutting ants—that the defenders have chiefly to deal, but all those who have dwelt in the Tropics know to their cost what it means to disturb the pugnacious ants dwelling in certain trees. There are several other insects which are carnivorous and, by preying on those which do damage to the forest, are the real friends of the forests, together with the birds and other animals which devour the plant pests. Among the insects most useful may be mentioned the ground and tiger beetles and the ichneumon wasps, and, for destroying Coccidae, the lady-birds. Further mention of these useful animals will be made as occasion occurs.

To turn to *forest destroyers*: they are so numerous and so varied that it is a wonder that there are any forests left to fight them, and the plant enemies which also attack them. But notwithstanding the marvellous recuperative forces of Nature many a tract has been deforested and denuded, and barren expanse meets the eye where formerly leafy trees cast a grateful shade over the ground.

First of all there are the insects, among which the Coleoptera, Orthoptera, and Lepidoptera are probably the most destructive, although the Neuroptera and Hemiptera are also the cause of much damage. The Governments of tropical countries are becoming aware of the damage done by insects not only to forest crops but to cultivation, and to the lives of animals and men, and several of them have already appointed entomologists in order to study these pests. With the help of these as well as of foresters, who make the study of insects affecting forest life their particular hobby,

knowledge of their habits is being gradually acquired, as well as of the remedies necessary to fight successfully against their inroads. Here it is only possible to deal very briefly with them.

Some insects attack only certain plants, while others are more catholic in their tastes, and some will attack the roots, or the wood, or the leaves or shoots of a tree as the case may be, and some again may, during one stage of their growth, attack the roots, and during another the leaves and shoots, as *e.g.* the cockchafers (*Melolontha*). Some weevils (Curculionidae) attack the seeds of trees, while others go for the leaves, and others again attack the cambium zone, and often ultimately girdle the trees and thus kill them. In a report on the forests of Mauritius,[1] one of these is mentioned as doing great damage to forest trees, and the introduction of woodpeckers is recommended. Among other wood-boring beetles perhaps the most injurious are the Scolytidae, which bore galleries in the wood, bark, and bast of trees and injure the cambium zone, the Buprestidae, and the Cerambycidae. As many of these beetles first get an ingress into the forest by attacking unsound and dead trees, it is desirable that all such should be removed as early as possible, as otherwise the insects are liable to turn their attention to healthy trees. A great safeguard is also to keep the forest mixed, as a pure forest, once attacked, is more liable to suffer from wholesale damage. Among the Lepidoptera the caterpillars, both of moths and butterflies, do damage in eating leaves and young shoots. No such damage as that done in Europe by the nun-moth (*Liparis Monacha*) has been observed by me in tropical forests, probably because they are of a more generally mixed character, and perhaps, partly, owing to the abundance of insectivorous birds or other enemies.

One of the greatest of insect plagues, not only in tropical but also in extra-tropical countries, chiefly in Asia and Africa, are migratory locusts, the most common

[1] F. Gleadow, *Report on the Forests of Mauritius*, 1904, p. 57.

of which are perhaps the *Schistocerca peregrina* and *Acrydium aegyptium.* These settle in huge swarms over a country and devour everything green that comes within their reach. Various methods of destroying these insects have been adopted with success in some places; but their destruction, while in the winged stage, is not practicable, and the best thing to do when swarms try to settle over a certain locality is to scare them away with noisy instruments, as by beating tom-toms, old kerosene tins, etc. If possible, the pest should be destroyed either while still in the egg or while in the wingless larval stage. In Cyprus and Tunis the purchase of eggs at so much per kilogramme has met with success; but in a country of which a large proportion consists of steppe and savannah it is often not possible to discover the breeding grounds. The same applies to the destruction of swarms of larvae—"hoppers" as they are called—which devour the vegetation close to the ground as they advance over it. On very smooth ground a good deal can be done by beating them with branches of shrubs or fronds of palms, as the slightest injury prevents the insects from reaching maturity. Trenches can also be dug across their line of march; into these they fall, and can be exterminated by stamping earth on them. In a bush country a large number can also be killed by setting fire to them. Attempts have been made, unsuccessfully so far, to infect the swarms with parasitic fungi. Care should be taken, in such countries, to protect all insect-eating birds and also the insects which attack them. In the Sudan it was found that large numbers were destroyed by the Tachina fly, which deposited its eggs in the bodies of the locusts. Some of the Cantharididae or blister beetles also lay their eggs within those of the locusts.[1]

Non-migratory locusts and grasshoppers, as well as crickets, often do considerable damage in nurseries and young plantations, and should be destroyed. Here again

[1] *Second and Third Reports of the Wellcome Research Laboratories,* Khartoum, 1904 and 1906.

it is in the larval stage that they can be captured most easily and killed.

Among the most deservedly unpopular insects of the Tropics are the white-ants or termites. But to the forester they are of concern chiefly on account of their attacks on timber after it has been felled. It is not common for them to attack healthy plants and trees, but should the latter become affected from some other cause their tissues are very soon attacked. It is for this reason that termites are particularly dangerous in nurseries and young plantations before young plants have had the time to recover from the shock caused by transplanting, and that, in such places, it is essential to move the seedlings most carefully in order that the root-systems may be disturbed as little as possible. In permanent nurseries it may be feasible to prick out transplants or cuttings into beds with a cement bottom; but this is not always practicable in temporary nurseries, and the seedlings should either be raised in baskets or taken up with large balls of earth. Various compounds have been tried to preserve trees from attacks of termites, with more or less success, but as the chief damage is usually done to the roots or the collum, they are not of very much use against these injuries.

Where those useful animals, the ant-eaters, exist, they should be strictly preserved; bears are also useful in destroying termites. Considerable damage to young shoots is often caused by the attacks of Aphidae and Coccidae. Only recently (1909 and 1910) the fine avenues of *Albizzia Lebbek* in Cairo have been destroyed by the former. It is evident that pure forests are particularly liable to the ravages of these insects, and that a mixture of species is a great safeguard. The protection of birds or insects which feed on these, such as certain kinds of lady-birds, bugs, etc., is also essential.

Damage is also done by certain ants which cut away the leaves, by wood-boring bees and wasps, but as a rule it is not on a wholesale scale.

Among other animals doing damage to the forest

the following may be mentioned. The *Iulus*, one of the Millipedes, does damage by eating young seedlings. They can be destroyed by putting down poisoned food.

Snails are reported in some places[1] to do considerable injury not only to the foliage but to healthy shoots of young plants. In such places the introduction or preservation of the hedgehog is recommended.

Various birds live on the seeds of trees and thus do damage to the natural regeneration; and I have seen many trees along the Blue Nile the branches of which had broken with the weight of enormous numbers of small migratory birds perching on them. Woodpeckers do a certain amount of injury to trees by pecking at them in search for insects, but they do a great deal more good than harm. Parrots and toucans also make their nests in hollow trees, but they usually attack soft-wooded or unsound trees.

The Rodents can be classed generally as great enemies of the forest, especially rats, porcupines, and hares. Of these the rats, when there is a plague of them, do the greatest amount of destruction. An example of this is quoted from Berar in the *Indian Forester*.[2] In this case, not only roots but young bark and even the wood of certain species, such as Teak, *Butea frondosa*, *Odina Wodier*, and *Garuga pinnata*, were attacked and many killed. I myself saw the results of a similar invasion at Newara Eliya in Ceylon. Young trees were attacked and the bark eaten away sometimes to a height of four or five metres. Fernandez (in the article referred to above) mentions that the damage was more considerable where the soil was soft and loose, and practically absent on hard soil and where grazing was taking place. It might therefore be of use to drive herds of cattle into forests thus infected, provided that the damage to young plants is not likely to be enhanced by this method. Hares and porcupines have both shown a great partiality for *Hevea braziliensis* in plantations

[1] R. Thompson, *Report on Mauritius Forests*, p. 39.
[2] E. E. Fernandez in vol. xxviii. No. 4.

of this tree. In such places the protection of the plants by wire netting may become necessary if other means are insufficient to deal with the evil, as by setting traps or by smearing the stems of trees with an offensive substance. All the carnivora, whether birds or small mammals, and also non-poisonous snakes which prey on these rodents, should be protected wherever there is any danger from their attacks.

Deer and certain antelopes do damage to the forest, not only by browsing, but also by rubbing their horns against saplings. This latter injury is particularly the case with deer when they are shedding their velvet. There is no doubt that these animals should be kept out of plantations by fences. Barbed wire is not always sufficient, as small deer and antelope will hop between the strands unless they are closely set together, and the larger animals often charge blindly into the wires, notwithstanding the wounds they obtain, until they break down the obstruction. In the forests the thinning down of the game may be left to sportsmen. There is only too much danger that these beautiful animals may be thinned out of existence. They have also many enemies in the shape of carnivora, of which the most destructive are the wild dogs which hunt them in packs.

Other horned animals, such as buffaloes, gaur, giraffes, especially those found in large herds, browse heavily, and they also do a considerable injury to young growth by trampling it down and in hardening the soil. Bears eat wild fruit, but may thus help in the distribution of seed; they are also very useful in eating up termites. Wild pigs do a certain amount of harm by eating seed and uprooting seedlings, but, on the other hand, they are useful in working up the soil and preparing it for the reception of seed.

Elephants, both the Asian and the African, are responsible for a good deal of injury to the forest. They not only break boughs in order to feed on the bast and leaves, or uproot bamboos to let their young feed on the younger culms which come out in the centres of the

clumps, or bark certain trees for medicine, but they do a lot of wanton damage, and vent their spleen more especially on objects of a white colour. For example, I have known Asiatic elephants to destroy a number of whitewashed boundary pillars, which after that had to be coloured grey; but in Africa not only have I seen a large number of white notice-boards torn off by them, but, in the adjoining forest, where there were a considerable number of white-stemmed *Acacia Seyal* var. *Fistula*, nearly every one of them had been uprooted or broken wantonly and without any indication that they were the favourite article of diet. It is, therefore, desirable that these animals should be kept out of young forests; they can be scared, for a time at least, by beating drums or, at night, by lighting fires, which, however, may be more dangerous to the forest than the elephants unless they are carefully watched. For young plantations a strong barbed wire fence may be quite sufficient, both for elephants and hippopotami, these pachyderms having a sensitive skin. If that is insufficient a stronger fence must be put in with the stakes driven well in and propped up on the inside, as elephants use their weight in pushing and not in pulling. A ditch, 2 metres deep and 2 metres wide, with vertical sides, should also keep out elephants, which are not capable of jumping, but the banks should be kept vertical and in good condition. Where the soil is loose, therefore, such a ditch is not sufficient, as the elephants will soon make an inclined plane by breaking the earth down with their fore-feet, and a fence is necessary on the inside bank of the ditch. In order to clear the neighbourhood of these animals it may be desirable to encourage the hunting or catching of elephants.

Among the most mischievous and destructive animals in the Tropics are monkeys. And they are not only destructive, they are wasteful. Anybody watching monkeys feeding will see that when, after pulling off a handful of leaves and shoots, they begin to eat it, they at the same time see another, apparently more

tempting morsel, and throw away what they have in their hands to get it. Thus the ground below gets littered with the leaves, twigs, flowers, and half-eaten fruit. Not only is damage done thus, but branches are broken by the monkeys jumping and running about on them. They also do a lot of harm by eating the eggs of birds, and thus make away with a lot of useful insect-destroyers. When they are in sufficiently large numbers to do much damage they should be got rid of, either by killing them or by driving them away. As the shooting of monkeys is not a pleasant business it may be preferable to get rid of them by poison. One of the greatest enemies of the monkey is the leopard (or in America probably some other member of that tribe, such as the puma or jaguar), and in such places it may possibly be to the forester's advantage not to molest them.

The above is, probably, a very incomplete statement of useful and hurtful animals, but it must suffice to direct the attention to one of the many problems which face the forester when he undertakes the management of forests.

CHAPTER V

MAN AND DOMESTIC ANIMALS

Man, and with him the domestic animals which he controls, are, unfortunately, to be reckoned as the most potent factors in the destruction of forests. On the other hand, it is also man, once he is aware of the necessity of protecting forests, who steps in and saves what remains; at the same time improving it and in places creating new forest crops for the benefit of future generations. It is this long-deferred reaping of what has been sown which has been, and still is, the greatest obstacle to spending money on forest improvement. We foresters have to lay to heart the punning motto inscribed over the doors of a German Forest School: "Wir sehen nicht, was wir säen und säen nicht, was wir sehen";[1] and we must not lose courage when present-day financiers, desirous of obtaining quick returns for money invested, demur at the spending of money on crops the benefits of which will accrue to their successors.

In olden times, when the greater part of the globe was forest-clad, man helped himself to what he required, and allowed his herds to roam uncontrolled wherever convenience or safety, added to a sufficient pasturage, could take them. As the area under forests diminished, the value of their products increased, and the more powerful people or clans excluded others from the benefits of the forest; but they themselves, for a long

[1] "We see not what we sow, and sow not what we see."

time, did not regulate their own demands. It was only gradually that mankind became aware that, with the destruction of forests, not only did the supply of many benefits cease, but that other evils followed in the train of the destruction. Thus forest laws were gradually evolved, first in Germany and France and then in other countries; but even now in some civilised countries, such as the United States of America and Canada, the Forest Departments have not yet been successful in staying the wholesale destruction of forests, although they have got as far as to get it admitted that the supplies of timber are by no means as inexhaustible as they were held to be, and that they are within measurable distance of total disappearance.

In the Tropics, large portions of which are inhabited by uncivilised tribes, some of which are nomadic, and others by people who have not been educated to the necessity of forest preservation, it is only in recent years that anything has been done to stay the destruction of forests, and even in these regions a large percentage of damage has been done by European settlers. To the Indian Empire belongs the credit of taking the lead in tropical forest management, and gradually other Governments are following this example. But in some cases only a small beginning has been made, while in others nothing at all.

We shall now turn to the nature of damage done to the forest by man and domestic animals. In order to follow the sequence of the preceding chapter I shall first refer to the domestic animals.

The injury to forests done by domestic animals is caused by grazing and browsing, and to these can be added the lopping of boughs for fodder and litter.

There are few domestic animals in the Tropics which feed entirely on herbaceous plants. Most of them will not hesitate to attack the leaves and succulent shoots of trees or saplings of certain kinds which come within their reach. Among them the goat must be given the first place as a forest destroyer, for it not only eats

seedlings and young shoots which come within its easy reach, but it stands on its hind legs and drags down branches of young trees. As it is a prolific breeder the damage which it does unaided is immense, and this damage is intensified frequently by the help of the goat-herd, who pulls down branches or lops them, or even cuts through young trees, in order to let his beasts feed on the crowns. In places where fellings have been made, the goats, unless restricted, will go and nibble at and destroy the young coppice shoots as they show themselves, and ultimately kill the stumps. The only animal which can compare with, or even exceed, the goat in destruction of forest is the camel, which will strip a whole twig of bark and leaves, even when it is armed with spines or prickles. Owing to its greater size the camel is able to carry on its depredations to a much greater height than the goat, and also to reach much farther into the crown of a young tree. These two animals together have done an enormous amount of forest destruction. The late Mr. Floyer, in an article which appeared in the *Kew Bulletin*, commenting on the names of certain valleys and other places which are called after trees, no trace of which is now to be found within the locality, states that before the Muhammadan invasion all the "Wadis"[1] of Upper Egypt were well stocked with trees, and that their conversion into desert has been caused by the large herds of camels and goats which were brought into the country, the latter assisted by the billhook of the goat-herd. Later, the charcoal-burner came and even stubbed up the roots and other remains of woody vegetation left behind, and the work was complete. To this is probably due the formation of sand-drifts which now invade the country. Examples of immense injury due to goats might be multiplied; their power of doing evil is so much recognised in European countries that they are excluded from reserved forests. Buffaloes are also animals which browse as much as they graze, and in certain parts of India they

[1] Valleys and watercourses.

do not only browse, but their owners lop forest trees for them. In the Tropics it is not possible to consider sheep as being entirely dependent on grass for their existence. They live on what they can get, and if grass is absent, as is often the case after fires have swept through the country, they will eat the succulent shoots of shrubs and young trees.

But it is not only by eating and tearing at shoots that damage is done to the forest. Perhaps even more considerable harm is done by the stamping of innumerable hoofs on the soil. On slopes, the surface soil is first loosened and then either blown away by the wind or washed away by the next tropical downpour. The débris which are thus carried off may be deposited over fertile fields in the plains, and thus damage is not only done to the forest itself but to cultivation. One of the first measures adopted in the re-afforestation schemes of the Alps is to exclude grazing from the catchment basins of streams. In the hills of Hushiarpur in the Panjab, loose sandstone hills have been denuded, and thousands of acres of fertile land have been covered by sterile sand, owing to an unchecked grazing of goats and other animals.[1]

In the plains the soil gets beaten down and hardened. There is no mistaking a forest in which heavy grazing is permitted. Many of the trees are stag-headed and they look hide-bound. Undergrowth is scanty and consists largely of thorny shrubs, under the protection of which perhaps some saplings of forest trees may struggle for existence. What seedlings of trees there are elsewhere, either come up under the shelter of large trees where, herbage being scanty, the soil has not been trampled down so much, or, if found elsewhere, they are stunted and ill-shaped from being constantly trampled down.

The problem of dealing satisfactorily with claims to pasture cattle is one of the most difficult for the administrator to solve. On the one hand there is the

[1] B. Ribbentrop, *Forestry in British India.*

forester, fearful of damage to his forest crop, and on the other the cattle-owner, who may have been accustomed from time immemorial to pasture his cattle, unchecked in numbers, wherever an abundance of fodder and of water were to be found. These people have no idea that a country may become overgrazed, and many tribes, whose wealth is their herds and flocks, do not readily part with a certain number every year in order to keep within the limits of their supply. In countries where there is no civilised government this thinning out is done by means of raids, or by unchecked cattle-plague; but where the inhabitants are under control and live in peace, the flocks are apt to grow out of all proportion to the capability of feeding them properly, and a clamour for more grazing-ground arises, or a complaint of encroachments by the expanding flocks of other tribes or villages. The tendency of the civil administration is to shirk interference at the outset and to wait till the situation becomes acute. This is especially the case in a recently settled country, where it is desirable to keep a rather turbulent portion of the population content. And there is no doubt that over drastic measures have led, in places, to widespread discontent which has ultimately resulted in setting back the encouragement of other useful forest measures. In such places it is desirable, therefore, to introduce protective measures carefully. The first step will be the prohibition of herds belonging to new-comers who have never exercised the right of pasture in the district. Then in most districts there are large areas which are natural grazing-grounds and can be marked down as such. If these do not suffice it is desirable, after taking a census of the cattle, to have the rights defined and settled and to open certain forest lands to grazing, a record being kept of the number of cattle permitted to pasture, and to see that this number be not exceeded. If the forest is to be maintained as such, certain areas will have to be closed in rotation, in order to allow a young crop to grow up sufficiently to be above the reach

of cattle. In such forests graziers are to be allowed on no account to set fire to the grass in order to bring out a new crop of tender herbage. Finally, if the area is overgrazed and there are no means of regulating the grazing to the limits which render a rational forest management possible, it is useless to attempt the latter. Although there is a maxim in law that no right can be exercised so as to ruin the land in or over which it exists, political reasons may in some cases override these rules. As an example, I may quote a case which came within my own experience not long ago. The new town of Port Sudan, on the Red Sea, was in want of a fuel reserve in order to provide for the regular supply of firewood to the inhabitants. The settlement provided that the Government was vested, free of all rights, in the land within a radius of ten miles of the town. Within that area there was a wood, chiefly composed of *Acacia tortilis*, which was well suited for this fuel reserve. A survey of the forest land was made and a forest officer drew up a working plan for the same. As the forest was to be worked on the coppice system, a clause in the working plan provided for the closing to grazing of the compartments cut over for a sufficient number of years to ensure the safety of the new regrowth. Thereupon the Governor of the Province, although the area was declared free of rights, stated that it was not possible to keep out of the woods or any portion of them the herds belonging to nomad Arabs, who always came down when the water-supplies and the pasture in the hills were exhausted. As the working of a forest, especially on the coppice system, under such conditions would have meant hastening the total destruction of woody growth, not only was the fuel reserve given up, but regulations had to be published prohibiting absolutely the cutting of wood within these areas.

As regards the number of cattle which can be admitted into a forest without causing permanent injury,

it is not possible to lay down a hard-and-fast rule that so many of any special kind may be allowed per hectare of forest. Each forest must be treated according to its own merits, for what may be permissible in one might be extremely hurtful in another, and *vice versa*. In Europe,[1] it is considered that large milch cattle require per head from 4 to 5 hectares (10 to 12½ acres) of good pasture for the whole summer, 2 to 3 young cattle or 7 to 10 sheep being considered as equivalent to one head of full-grown cattle.

In India, in places where large numbers of buffaloes, camels, or elephants are kept, considerable damage may be done by lopping for fodder. A large number of species are suitable for buffalo fodder; for camels, boughs of *Ficus religiosa* are usually lopped; and for the elephant the *Ficus bengalensis* in India, and *F. religiosa* in Burma. What has to be watched is, that unnecessary damage to the trees is not done by the men cutting fodder. It often happens that, to save themselves the trouble and risk of climbing to the ends of the branches, they cut large limbs off, from which, as they lie on the ground, they lop the boughs which they take away for fodder.

It remains to be said that damage done by grazing is generally greater in monsoon and savannah forests than in the evergreen forests of the wet zone, where, under the dense leaf-canopy, little herbage springs up.

One of the greatest evils attendant on grazing is that caused by forest fires. It is chiefly in order to obtain a fresh crop of tender grass that fire is set to a forest or to the pastures in the vicinity of the forest, whence the fire penetrates sometimes miles away into the woods. In their progress the flames, striking the outlying trees with the greatest impetus, do most damage to them, and gradually kill them off and thus reduce the area of the forest.

Forest fires, although they are chiefly due to graziers, may arise from a strange variety of causes, as the perusal

[1] Schlich's *Manual of Forestry*, vol. iv., by W. R. Fisher, p. 41.

of forest administration reports will soon show. First of all they may be caused by act of God, such as by lightning. I have also heard of a case where a forest was set on fire by a boulder of quartzite rolling down a slope and, in striking another rock, giving out a spark which set the dry herbage and pine needles close by on fire. It is said that dry bamboos or branches rubbing together in the wind may also cause fire, but I know of no authenticated case. The Duke of the Abruzzi, in his exploration of Ruwenzori, found the traces of a fire among the Tree-Senecios, probably due to natural causes, high above the habitations of man.

In countries where dangerous wild animals abound, such as elephants, rhinoceros, buffalo, tiger, lion, or leopard, fire is often brought into requisition to clear the paths through the forest and to enlarge the field of vision or in order to drive the animals away. There are also cases of mischief or revenge, as where some villagers repay the administration for excluding their cattle from favourite grazing-grounds, and others of simple curiosity or carelessness; and it may unfortunately happen that, in burning fire-lines to protect the forest from invading fires from outside, the wind may suddenly veer round and enter the forest, notwithstanding the efforts of the forest staff.

The evergreen forests of the wet zone are the most immune from the dangers of forest fires, but they are not entirely so, and where they stand close to grazing-grounds which are set fire to every year they gradually give way to the onslaughts of the fires. In the wet montane zone of Ceylon, for example, wide tongues of grassland extend into the forest, which are due to the encroachments of fires coming from the drier side of the island. Upon the cleared area a herbaceous vegetation has established itself, the remains of which form a sour humus, the properties of which are such that forest trees can with difficulty re-establish themselves.[1]

[1] H. H. W. Pearson, "The Botany of the Ceylon Patanas," in *Linn. Soc. Journal, Botany*, vol. xxxiv.

The more open the leaf-canopy and the more scattered the trees the greater will be the impetus of the flames, which gradually but surely kill them out, and finally reduce the area to savannahs or steppes. The so-called "Patanas" of Ceylon are an example of this. In the low country there is still an open savannah-forest, which is aptly called the "Park-country," but higher up, on the slopes where the surface soil is made friable by the fires and soon washed away by the monsoon rains, the trees have been killed·off more rapidly, the herds of cattle helping in the destruction, and in loosening the soil; and what is left only bears a very coarse grass, or coarse sedges, which are only capable of affording fodder to cattle while still young and tender. Thus fires continue and the tree growth is confined almost entirely to the thick-barked *Careya arborea* (Fig. 14).

When a fire enters a forest it kills many young seedlings outright. Among the stronger ones, with well-developed taproots and capability of giving out coppice shoots, the damage may be limited to killing them down to the ground; saplings and poles are often so injured that they lose their straightness and vigour of growth. Among the trees the Conifers are those which suffer most damage from fires, which are intensified by the resin exuding from wounds, while among others those provided with thick outer bark are the most immune; nevertheless, fires give rise to unsoundness wherever the scorching fire has been so intense that it has killed the cambium. Existing unsoundness will be intensified, and fire will often penetrate into hollows in the stems and branches, sometimes smouldering for months together, and finally bringing the tree down, when the scattering of the burning embers may easily cause another fire to pass through the forest. Finally, flowers or fruit are destroyed in large quantities, and the shrivelling up of the leaves causes a temporary cessation of growth and consequent diminution in the production of wood, or an uneven development of the timber.

For some years past there has been a good deal of

FIG. 14.—Hills in Ceylon deforested by fires and grazing.

correspondence in the *Indian Forester*, chiefly on the effect of fire-protection in the teak forests of Burma. It has been maintained, with a good deal of evidence to support this assertion, that, in the non-protected forests, the number of seedlings of teak is much larger than in the protected areas, and that saplings and poles maintain themselves also better in these areas than in the protected forests. In order to support this, enumerations of teak trees were carried out both in protected and in non-protected areas, over places where enumerations had been made some twenty or more years before, and these enumerations indicated an increase of saplings and poles in the unprotected areas, and a decrease in those which had been protected. The reasons advanced for the gradual decrease of the teak trees in protected forests are: (i.) that the seed falls on a thick layer of dry leaves which keep it from the soil, and the rootlet from penetrating into the latter, and that in the following year those seedlings which have managed to germinate are covered up by another layer of leaves which suppress them; (ii.) that fire-protection favours the development and spread of other species, more shade-enduring than teak, which usurped its place and gradually ousted it, the most formidable invader being bamboos, especially *Bambusa polymorpha* and *Cephalostachyum pergracile*, especially the former, which grows to a larger size, only seeds and dies down once every fifty years or so, and suppresses all shade-avoiding species which it overtops.[1]

It is also maintained that the fires in these forests are mere ground fires, that they kill small seedlings only down to the ground, and that these are soon able to send out new coppice-shoots, and that with saplings, poles, and trees, excepting perhaps those on the decline, the damage done by these fires is so small that it is covered many times over by the cost of fire-protection.

[1] Since writing the above, I have seen a forest officer who informed me that in some teak forests of Upper Burma which he had administered, fire-protection had changed the character of the forest; it had become evergreen, naturally fire protected, but teak had ceased to reproduce itself.

Several writers deny that the damage done is as light as is contended by the advocates of abolition of fire-protection. Even so, if it be admitted that a considerable reduction in the marketable value of timber is caused by fires, the problem which faces the forester is: Is it better to have a crop which continues to be constituted largely of teak, many of which, however, are damaged by fire, or to have a crop which will not so be damaged by fire (although it may be injured by suppression), but which is steadily diminishing? Undoubtedly, the former will at once appear to be the lesser evil, for cultural operations in the way of removing the dominant bamboos or other trees would not only not be sufficiently efficacious but would be probably beyond the capabilities of the forest staff, both as regards available labour and funds to pay for it. As, however, there may be certain factors which have not been taken sufficiently into consideration, the Government of India, with wise forethought, have directed that experiments be carried out side by side, with and without fire-protection, in different parts of Burma, in order that all facts be carefully studied on the spot and hasty decisions be not arrived at.

For the teak forests of the Indian peninsula, which are not threatened in the same way by invading bamboos and other shade-enduring species, the consensus of opinion is strongly in favour of fire-protection. It must be said also that in these forests forest fires are probably much fiercer than those of Burma, and that the damage done by them is much greater.

A similar treatment with fire as proposed for the Burma teak forests has also been suggested for the Sāl (*Shorea robusta*) forests of Assam, on account of the heavy undergrowth of shrubs, canes, etc., which springs up under the cover of these forests and suppresses the young growth of Sāl. But this proposal, if followed, is much more difficult to carry out than in the Burma forests; for Sāl, according to all accounts, is more sensitive to fire, and its seed, which is very delicate, would be

hopelessly destroyed by fire, whereas a slight scorching of the teak fruit, on the contrary, seems to stimulate germination.

In the Sudan it is a well-known fact that a fire passing through the open forests of *Acacia Verek* not only kills a large number of trees, especially those weakened by repeated tapping for gum, but that it also stops the supply of gum for the season. It is a curious fact that in the case of the Acacia, which is next in importance to the above in the production of gum in the Sudan, viz. *Acacia Seyal*, the same rule does not seem to hold, and that gum production appears to be stimulated by forest fires, although the quality of the gum is reduced by them.[1] In the forests of both of these species, the heavy growth of grass which springs up operates against successful natural regeneration, and experiments made show that the seed germinates and the seedling establishes itself best where there is no grass. It is therefore probable that, unless light ploughing in the sandy soil in which *A. Verek* thrives can be carried out expeditiously and cheaply on a large scale, it will be necessary to close certain blocks periodically to tapping, and by setting fire to the grass to encourage natural reproduction; and, when this is accomplished, they can be protected again from fire in order to enable the collection of gum to proceed.

It is out of the tropical zone, in the coniferous forests of North America, that forest fires cause the most awful devastation; in the Tropics I know of no forests which have to endure such destruction as that caused sometimes over thousands of square miles by a single forest fire in North America. So much, however, has become apparent that, apart from the consideration

[1] Recent research (see *Fourth Report of the Wel[illegible] [illegible] Research Laboratories*, Khartoum) seems to indicate that the [illegible] the gum-bacillus is due to ants. It is possible, therefore, that in the forests of *A. Verek*, where the trees are smaller and more scattered and the soil sandy and more easily heated, there is a greater destruction of ants by fire than in the denser and taller forests of *A. Seyal* growing on cotton-soil.

of the component species, fires cause a deterioration in the general character of a forest; but that protection, in some cases, favours the existence of less valuable species to the detriment of those which are of the greatest value to the owner, and that, in such cases, a careful study of the conditions will show how far it is desirable to relax the strictness of this protection. It is particularly desirable that fire-protection should be maintained in places liable to erosion. As an instance may be quoted the protection of the outer Himalayan Range, the Siwaliks, near Dehra Dun, where masses of silt and boulders were washed down in sudden floods and threatened the existence of the Ganges canal. Since the introduction of protection in 1882 the banks of these watercourses have been defined, the extensive chaotic masses of boulders getting covered by forest of *Dalbergia Sissoo* and *Acacia Catechu*, and the violence of sudden floods much reduced. The methods which are employed for protecting forests from fire will be described in another chapter.

When man began to cultivate the soil for its crops, it is most probable that he made a clearing in the forest near his habitation, set fire to the felled trees, and sowed his seed in the soil enriched by the ashes, and when, after cultivating the area for a number of seasons, he found that the crops were of a poorer quality, owing to the exhaustion of the soil, he felled a fresh area. This system of shifting cultivation is still practised on a large scale, especially by uncivilised tribes, where the population is scanty and the area under woody growth extensive. It is known in India under various local names, such as *jhum*, *kumri*, and *khil*, in Burma as *taungya*, and in Ceylon as *chena* or *hena*. But it is not confined to the Indian Empire and Ceylon; I have seen it used extensively in the Sudan, and it is most probably employed in other parts of the Tropics. As it has been found that the best type of forest gives the richest amount of ash, and that scrub, moreover, is full of thorns and a vexation to the feller, it is to the

former that, unless restrictive measures are applied, most attention will be paid. It is incredible how far the damage done by a single small community will extend, and, where the forests are not naturally self-protected against fire, the latter may spread to the adjacent blocks and cause damage far and wide. The area cultivated is abandoned after a period varying from two to five years, and it gets covered again by a secondary kind of forest, usually of a thorny character, or simply by sheets of dense inflammable grass, such as *Imperata arundinacea* or by bamboos, *Lantana*, or *Gleichenia* fern, the last on poor soil. Thus, for a poor crop of rice, sesame, *Eleusine*, or *Sorghum*, which may be repeated two or three times, the growth of a hundred years may be sacrificed. I have seen in Ceylon beautiful forests of satinwood and ebony thus thoughtlessly consigned to the axe and flame. In India it has been decided that this practice did not constitute a right,[1] but in Ceylon it is recognised as a right in Kandyan Provinces. It is evident, however, that even where the right exists, it cannot be exercised to the detriment of other property, and that here, as elsewhere, it can be defined and kept within strict limits. Where this practice cannot be abolished—and it may not always be possible to do so—it should be regulated. Certain areas should be set aside for this cultivation, of sufficient extent that, after a certain number of years, felling and burning can come back to the spot where clearing was done in the first year of the rotation. Thus in Ceylon a twelve years' rotation was adopted, and the areas set aside for chena cultivation were subdivided into four blocks, each of which could be cultivated for three years. In Burma, and on a very small scale in Ceylon, areas were granted on the understanding that tree seeds be sown with the last year's crop, so that, on taking up a fresh area, the villagers might leave behind the beginnings of a valuable forest crop.

[1] B. H. Baden-Powell, *Manual of Jurisprudence for Forest Officers*, p. 171.

But it is not only for temporary cultivation that large clearings of forest land have been made. Many of them have been made merely with the object of obtaining timber or firewood for the use of a community, or for export, or again for permanent cultivation. Within the last half-century or more, capital has been attracted to the Tropics and utilised for the cultivation of products in demand in civilised countries—such are coffee, tea, cinchona, cacao, coconuts, and rubber. Large companies have been formed which have been able to carry on the cultivation on a large scale and to make extensive clearings. These companies selected the most suitable soils, a great part of which, or as great part of which as possible, was under virgin forest. It is clear that, with the increased population of the globe, and with the greater demand for luxuries, it is not possible to jealously guard all forest areas; but there is a limit beyond which it is not wise to go, and there are places where extensive fellings may do an immense amount of damage to the country, such as by interfering with the water-supply or by causing silt and erosion. We may take Ceylon as an example of a country which derives its wealth very largely from the plantations created by European enterprise. It was with coffee that the first step was taken. The hill country was almost entirely covered by a mantle of dense evergreen forests. Fellings on a large scale were made, the trees felled being set alight in order to obtain ash, and also to save the labour and expense of cutting the timber up. The clearings extended at such a pace that not only were the catchment basins of all the important rivers threatened, but an additional evil arose from the large masses of silt which was carried into the low country, and in raising the bottoms of the rivers, caused the overflow of their banks and consequent floods, which entailed considerable damage to field crops, and by interruption of traffic (Fig. 15). The authorities, therefore, on the recommendation of the Director of the

Kew Botanic Gardens, forbade the sale of all Government land for clearing at an altitude of 5000 ft. (ab. 1500 metres) and upwards.

But, although commercial enterprise of recent days has led to the destruction of forests on a large scale, the reduction of the area under forest has been going on steadily, through centuries, wherever man has had the uncontrolled enjoyment of forest products. It

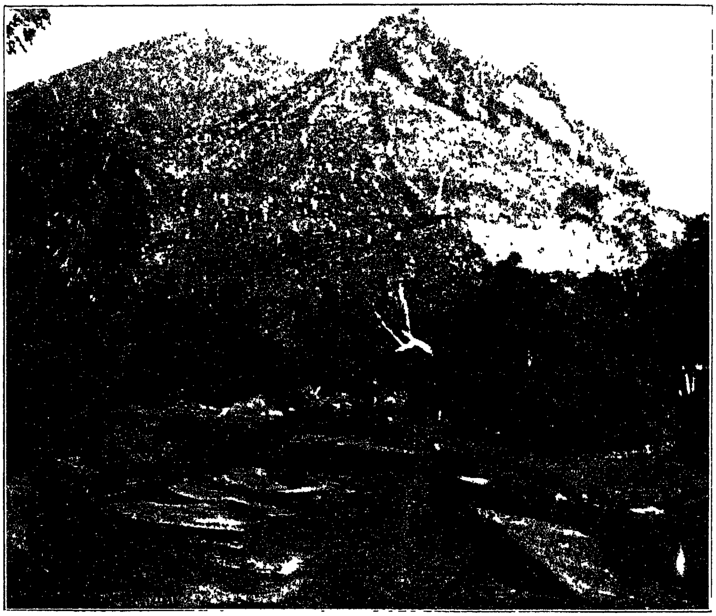


FIG. 15.—Showing a clearing for tea and consequent silt in a river, Ceylon.

requires a very high degree of education before communities can be led to perceive that they owe a duty to the unborn generations by preserving and, if possible, improving the capital which they hold in trust for them in the shape of standing forests. And it is for this reason that, in the management of State forests, forest administrators so often run against a dead wall of opposition on the part of the financial advisers of the Government, who, during their own administration of

the funds of the State, wish to be able to show a more speedy return for funds invested.

Another evil attendant on careless working of mixed forests is the cutting out of the more valuable species. These species are often represented in comparatively small numbers in a forest crop; and it is natural that, unless checked, prospectors will pick them out, and thus not only reduce the value of the standing crop, but injure the prospects of natural regeneration. Much damage has been done in this way to the teak forests of Burma and Siam, to those of satinwood and ebony, especially the latter, in Ceylon, and probably to the mahogany, logwood, and lignum vitae forests in South America, as also to the forests yielding gutta-percha in the Malay Peninsula. The most valuable cabinet wood of Ceylon, the Calamander or Coromandel wood (*Diospyros quaesita*), is now practically as extinct as the dodo, on account of the persistent persecutions which it has suffered; and another valuable cabinet wood, the Nedun (*Pericopsis Mooniana*), is threatened with a like fate.

The above statement shows the principal ways in which man shows himself an enemy of the forest, but he declares his hostility to one of his best friends in various other ways, such as by injury to trees while collecting minor produce; as, for example, in hacking at and setting fire to trees, and often to the surrounding forest, when gathering wild honey, by girdling and killing trees for their bark which he uses for tanning, in tapping them for gum or resin, in mutilating them for their leaves, which he may use for litter or manure or for tanning, and in gathering forest fruits. He commits numberless forest offences in preserved forests, and will adopt any means to enlarge his cultivation at the expense of the forest. As an illustration of this I may quote a case which happened in the early days of the Anglo-Egyptian administration of the Sudan, when the neighbouring Arabs set fires on the stumps of all the trees which had been cut in a coppice felling, and culti-

vated the ground, in order that, when the land settlement came to be made, they should be able to claim the land as having been under cultivation since the time of their forefathers.

Happily, man is not altogether a forest destroyer; and, in more recent days especially, the civilised races have come to understand and to believe, with many reservations unfortunately, that the destruction of forests must be limited, and that, by a proper treatment, they may not only be preserved but improved.

CHAPTER VI

INFLUENCE OF FORESTS ON CLIMATE AND LOCALITY

Two leading papers have recently brought before the public the subject of influence of forests on the climate of the surrounding locality. A leading article in the London *Times*[1] gives a vivid description of "Mekran," which is the name given to the long coastal region stretching almost from the Indus to the entrance of the Persian Gulf.

"The greater part of Mekran," it says, "is desolate and forsaken, a land desiccated by nature and shunned by man. . . . In the more arid parts the traveller comes upon forests of dead trees, which in that dry climate have stood still and stark for ages. Yet Mekran cannot always have been either so dry or so deserted." After describing the traces of great cities, of innumerable tombs on the hillsides, of vast masonry dams for storing water, and terraces for cultivations which are now dry and bare, without even a blade of grass, it adds: "Climatic changes have been at work, as in Central Asia, and perhaps deforestation was a contributary cause."

The other article, which appeared in the Allahabad *Pioneer*,[2] is on the subject of a statement made by the Chief of the Weather Bureau at Washington, in which he declares that "forests have no effect either upon the amount of rainfall or upon the severity of floods."

Mr. Moore, the official in question, is also reported

[1] May 3, 1911.

[2] December 9, 1910. See also *Indian Forester*, vol. xxxvii. Nos. 3 and 4.

to have quoted statistics to prove his case, and to have advised that forests should be preserved for themselves alone, or not at all, and that there can be no valid reason against decreasing the forest area "where homes and a well-fed people take the place of wild animals and wilderness."

Before going into the subject I may say that this assertion has been most vigorously opposed by other experts in America itself. It is perhaps useful to mention here a few of the countries which were at one time forest-clad, and are now suffering from the effects of denudation in consequence of the clearance of the forest areas.

The case of the Mekran mentioned at the beginning of this chapter is by no means a solitary one. The reports of Central Asian explorers show how a vast country, which was at one time capable of sustaining a large population, now lies arid and deserted. The same tale comes from Nubia and the Northern Sahara. In all of these sand-drifts now cover the scenes of ancient habitation. Greece, Italy, and Spain have all suffered from the removal of forests, and several parts of India bear witness to similar effects of deforestation. Ribbentrop[1] quotes two statements by independent witnesses in the Bellary district, where, in the space of something over twenty years, the rainfall decreased from about 45 inches to about 24; the formerly perennial streams drying up in the hot weather, the tanks which at first were never dry remaining low, and the climate becoming sultry. This was attributed solely to the destruction of forest for temporary cultivation.

It has been ascertained that the atmosphere over forests, up to a height which is said to amount to 1000 or 1500 metres (3000 to 5000 ft.), is charged with a much greater amount of moisture than adjoining lands which are not forest-clad. This is chiefly due to the fact that tree roots are able to search for moisture far deeper into the ground than other crops, and this fact

[1] *Forestry in British India.*

has been proved by experiments carried out in Russia, France, and India, where, under identical subsoil conditions, both inside and outside forests, it was found that the water-table inside the forest, although less liable to fluctuations, was lower than in places outside. When rain falls on a forest, the whole amount does not reach the ground, but a portion is detained by the crowns and trunks of the trees and re-evaporated into the air, thus further increasing the latter's store of moisture. If, then, a moist current strikes this cooler column it is apt to become condensed and to give out rain, and therefore there is every indication that forests increase rainfall.

Unfortunately, we have in the Tropics no absolutely reliable data to prove this. In India Blanford[1] compared the rainfall statistics over part of the Central Provinces, which had been deforested by shifting cultivation and subsequently preserved, and found that there was an increase of about 20 per cent in the rainfall in about ten years. Experiments carried out in France in the forest of La Haye, near Nancy, for thirty-three years showed that the rainfall on the edge of the forest was 6·1 per cent smaller, and outside the forest 23·3 per cent smaller, than in the centre of the forest. It was ascertained that these proportions were independent of the direction of the wind, and that the influence of the forest is also independent of seasons. In Germany the rainfall inside the forests is stated to be some 3 per cent heavier than outside.

There is, however, no doubt that much remains to be done before satisfactory data can be obtained, especially for the Tropics, where not only so much depends on the monsoon currents, but also on the character of the forests, which is of such a varied nature. For example, it can be readily understood that the dense equatorial forests give out a large amount of moisture, which becomes frequently condensed and returns in the form of rain; but it is of more real

[1] See *Indian Forester*, vol. xxxvii. Nos. 3 and 4.

importance to have some definite information for the areas covered with forests which are leafless part of the year, and still more for the more open formations, such as savannah-forests and thorn-forests. In the last-named class the forest is not only more open, but the organs of transpiration are formed so as to reduce evaporation to a minimum.

But if proofs are not sufficiently abundant as regards the influence of different classes of forests on rainfall, they are abundant as regards their influence in storing up rain-water and in preventing sudden floods. This is especially the case in hilly countries. On level land it is possible that, as the Chief of the Washington Weather Bureau asserts, ploughed land takes up and retains as much water as soil under forest does; this would, no doubt, depend greatly on the amount of humus and fallen leaves lying on the ground in the forest. But this is not the only consideration. Once the surface soil is filled to saturation the remainder flows off, and, under tropical rains especially, the rush of water within the forest is checked to a much greater degree than in open land; and not only is the danger of erosion greater in the latter, but there is also a greater danger of sudden floods due to the watercourses being filled more rapidly. Unfortunately, also, within the Tropics all cleared land is not under plough or under grass, but large areas are bare and barren, the result of a thriftless system of shifting cultivation; the surface is hard and not easily accessible to water, and the major portion of the water runs off and is lost.

The effects of denudation caused by rain-water on hill slopes have been studied and verified for many years. In Europe the damage caused in the Alps and in the Pyrenees has resulted in special legislation, and in the starting of extensive re-afforestation schemes. In America the Forestry Bureau has published much literature, accompanied by numerous excellent illustrations, in order to educate the people of the United States, and to make them realise the necessity of taking pre-

ventive measures ere it be too late. Mr. Roosevelt himself, in a speech delivered at Memphis ir 1907, said: "The National Forest policy, inaugurated primarily to avert or mitigate the timber famine which is now being felt, has been effective also in securing partial control of floods by retarding the run-off and checking the erosion of the higher slopes within the national forests. Still the loss of the soil-wash is enormous. It is computed that one-fifth of a cubic mile in volume, or one billion tons in weight, of the richest soil matter of the United States is annually gathered in storm rivulets, washed into the rivers, and borne into the sea. The loss to the former is, in effect, a tax greater than all other land taxes combined, and one yielding absolutely no return."

In India, as far back as 1846, Dr. Gibson, at that time acting as Conservator of Forests in Bombay, drew the attention of the Government to the damage done by reckless fellings, and the subject is obtaining much attention up to the present day, as is attested not only by a special pamphlet on forests and water-supply by Sir S. Eardley-Wilmot, late Inspector General of Forests to the Government of India, but also by frequently recurring articles in the *Indian Forester* and in the *Pioneer*. The effect of the denudation of the hills of Hoshiarpur on the country below has already been described, as also the beneficial result of protecting the slopes of the Siwaliks, in saving a large expenditure on protective works on the upper reaches of the Ganges Canal. Complaints of diminution of supply of water on the Cauvery river connected with the denudation of upper slopes have been frequent, and similar cases of landslips in the upper basins of Burman rivers, due to the same cause, are also quoted. The disastrous flood in Hyderabad, which cost so many lives, is ascribed to the bad forest policy of that state; while the Naini Tal landslip of 1880, which also resulted in serious loss of life, was due to the denudation of friable shaly slopes, and their exposure to torrential rains during the S.W. monsoon.

In Ceylon, the action of the Government in prohibiting the sale of lands at an elevation of above 5000 ft. has already been mentioned; but this action has not been sufficient to prevent the silting up of several rivers, notably the Kelaniya Ganga and the Mahaweli Ganga, and the consequent obstruction to navigation in dry weather and extensive floods during the monsoon. Indeed, an easy object-lesson is obtained by any one standing during a downpour of rain on slopes, some of which are covered with forests, while others bear tea estates. On the former, the streams come down almost as clear as crystal, while the water which runs off the surface of the tea estates, although its impetus is checked by numerous catchment drains, reaches the bottom of the slopes in a turbid flood. The water which comes down grass-covered slopes, although not as muddy as that from cleared lands, is by no means as clear as that which comes from forest land.

When rain falls on bare land, the soil at first absorbs the moisture, and, when this has been absorbed to saturation point, the water flows off to the nearest watercourse, carrying with it, in increasing proportion, according to slope and friability of the soil, the loose particles of the latter. The depth to which this saturation will take place also depends on the nature of the soil, the gradient of the slope, and the duration of the rain; but once this is accomplished the surface water runs off. On forest land, and by this I mean particularly in forest protected from fire, where the soil is either covered by a layer of humus, or, where this is not visible, where it contains in its upper layers almost invisible particles of this humus, and there is on the surface deposits of various vegetable débris, the saturation point is much higher than on bare slopes. It has been calculated that on forest-covered slopes about one-third of the water is detained. This water is gradually given off into the soil, led down by the roots of the vegetation growing in it, and feeding underground reservoirs, while the surplus water, checked in its impetus

at every point, finds its way in quiet flow to the bottom of the slopes. The forest is in fact a huge sponge which gives up its moisture gradually but steadily. It was my good fortune in Ceylon to be able to give to a class of forest students a practical example of the action of forest in retaining water and gradually giving it out. We were encamped at the foot of a huge mass of gneiss, the larger portion of which was bare, but on a portion of the summit of which was a small clump of forest overhanging a steep slope of rock. A heavy downpour of rain came and the rock streamed with water. After the rain, most of the rock quickly dried, but under the clump of forest a thin stream of water still trickled down, and it continued to trickle down during our stay of a few days at that place.

If forests have the effect of stopping erosion and of storing water to feed the supply of springs, they are also useful in draining water-logged soils. The most celebrated example of this exists in the Landes of Gascony, where plantations of the maritime pine have altered the character of the country from a fever-stricken waste to a thriving forest region capable of supporting a healthy population, to which the various forest works, especially the extraction of resin for turpentine, provide ample occupation. Similar instances can be found in the plantations of *Eucalypti* in the Roman Campagna and elsewhere. This is due to the faculty of forests, mentioned earlier in this chapter, of lowering the water-table.

As screens against violent and drying winds, forests are of great importance, and they are of greater importance still when these winds carry shifting sands before them. I have already mentioned the fixation of invading sand-dunes in Gascony by plantations of pine, and of the natural fixation of others in Kordofan by the *Acacia Verek*; and how, on the other hand, deforestation has in many places led to vast tracts in Asia and Africa being smothered by billows of sand.

Observations made in European forests show that

the temperature of the air and soil are lower than outside these areas, but that the variations are not so great, and that therefore the climate is more equable. This is no doubt also the case in tropical forests which are composed of trees growing close together, but how far savannah-forests or thorn-forests modify the climate in this respect is a matter of conjecture.

In countries which, like India, are subject to famines, forests play an important rôle. The reports of several Famine Commissions have referred several times to the probable effect of deforestation on the recurrence of famines, and on the reduction of springs due to denudation of catchment areas. In the meantime, the throwing open of reserved forests to the people and their cattle has been the means of providing the people with edible forest fruits and thousands of cattle with fodder.

Finally, as forests can be grown in many places which can bear no other crops, they provide occupation to a considerable population which would otherwise have to migrate elsewhere. Even at the present time (1911) a scheme of afforestation of parts of Scotland has been proposed in order to check the flow of emigration from that country to Canada.

PART II

FORMATION AND REGENERATION OF FORESTS

CHAPTER I

PRELIMINARY REMARKS AND DEFINITIONS

IN the first part of this volume it has been indicated that, under varying conditions of soil, climate, and locality, the forest vegetation is liable to variations, which are further affected by the fauna and population of the country. It is the business of the forester to study these various factors, and to apply his knowledge, both in the creation and treatment of forests under his charge, in order that they may reach and maintain the maximum of utility for the benefit of the proprietor. In so doing he is said to have the forest under "sylvicultural treatment."

The chief object for which forests are grown and tended is for the production of timber or for firewood; but there are some which have as their chief asset some other produce, such as gum, gutta-percha, or rubber. There are other woods which are created or maintained for other purposes, such as the fixation of shifting sands or unstable slopes, the drainage of swampy localities, for protection against wind, or even merely for the addition to the local beauty of the locality, or for the preservation of game, but these we can leave out of consideration.

In the formation of new woodland crops, where none previously existed, the forester will generally rely on artificial means, as *e.g.* by sowing or planting, although in some cases, where the land is in the vicinity of already standing forest, he may rely wholly or in part

on natural sowings shed from the forest trees close by. And in already existing forest the regeneration may be obtained either wholly or in part by these artificial means, or it may be obtained either by seed shed by parent trees in the forest, or from shoots or root-suckers given out by the stumps of trees felled, or from their roots. This leads to a broad division of creation or regeneration into *artificial* and *natural*, the carrying into effect of either of which may be done in different manners.

Once the regeneration has been secured, the work in the forest is devoted to the development of the young crop to maturity, and of guiding this development by means of other operations to the point where it reaches the greatest amount of utility to the owner.

Before proceeding to a description of the different measures which have to be taken, it will be useful to give the definitions of certain technical terms which are in constant use.

A *seedling* is a plant which has sprung direct from seed; in forestry, however, the term is usually applied to such a plant in its youngest stage, *i.e.* when, in the case of young trees, it is not much more than one metre (3 to 4 ft.) high. When it has reached that height it becomes a *sapling*, and it continues as such until the time when, growing in forest, it begins to lose its lower branches, when it becomes a *pole*. It remains in that stage until it has attained its full height, when it becomes a *tree*. Botanically speaking, a *tree* is a plant which is capable of carrying a single stem, under forest, up to about 8 metres (25 ft.), without giving out any main branches, while a plant of similar mode of growth but of lesser size would be called an *arborescent shrub*; and the term *shrub* is applied to woody plants which naturally branch into several stems from near the ground, the term *under-shrub* being given to those woody plants which do not exceed one metre in height.

When the floor of the forest is covered with a mass of seedlings, under-shrubs, and other low plants, this

carpet is called the *undergrowth*; when it is covered by saplings standing so close together that their branches interlace, this mass is called a *thicket.* No special term has been given in English to a dense mass of poles; it is merely called *pole forest.*[1]

A tree consists of three parts, the *stool*, the *bole*, and the *crown.* The *stool* is the portion of the stem which, after the tree is felled, remains in the ground. The *bole* is the portion of the stem or trunk from the ground to the first branch, and the *crown* is the upper portion which bears branches and foliage.

A *stool-shoot* is a shoot given out by the stool, and a *root-sucker* is a shoot given out from the roots.

The mass of foliage formed by the crowns of trees in a forest is called the *leaf-canopy.* The latter is said to be *complete* when the crowns are so closely packed that their branches interlace; when the crowns touch, but not at all points, the leaf-canopy is *open*, and when the crowns are free of contact with each other it is said to be *interrupted.*

The forest-growth standing on any given area is called the *stock* or *crop.* It is said to be *complete* when the area is fully taken up by tree-growth. A *pure* crop is one consisting almost entirely of one species, while in a *mixed* crop two or more species may be associated. Of these, those which, owing to their importance, have most bearing on the treatment of the forest, are called the *principal* species. Other species, which, although of some importance, are of less value, either on account of their value or numbers, are called *auxiliary* species, and the remainder *accessory* species. Trees forming pure forests are said to be *gregarious*, while those which only occur scattered through a crop are called *sporadic.*

A *regular* or *uniform* crop is one composed almost entirely of trees of approximately the same age and size, provided the leaf-canopy is fairly complete. The *habit* of a tree is the shape which it usually assumes, as

[1] In French *perche* is a pole, and *perchis* pole forest.

e.g. with pyramidal, rounded, or flat or umbrella-shaped crowns. *Cover* is the action of the crown on the space vertically under it. A plant vertically under the crown of a tree is said to be *under cover*; those not under cover are said to be *in the open.*

Plants which can exist under cover are called *shade-enduring*, while those which can only thrive in the open are called *shade-avoiding*—such a plant, if it gets under cover, will have its growth retarded; it will, in other words, become *suppressed.* In the struggle for existence between component trees of a crop, those which are left behind in the race for height are at first *dominated*, and if they fall still more behind and come under cover of other trees they become *suppressed*, unless very shade-avoiding. Those which keep the lead are *dominant.*

A tree or crop becomes *exploitable* when it has reached the most useful dimensions for the purpose for which it is destined by the proprietor. To *exploit* a forest is to fell it according to sylvicultural principles.

The *rotation* of a crop is the period from the time when its component trees have germinated to that when they are felled.

By *advance-growth* is meant the crop of seedlings and saplings which have sprung up in a forest before any regeneration fellings have been undertaken.

A *nurse* is a tree or shrub intended to shelter young plants until they are strong enough to live in the open.

A *coupe* is the area over which a felling is made.

A *high forest* is a forest the component trees of which are mostly sprung direct from seed, while a *coppice* or *copse* is a wood or forest the trees of which are most of them stool-shoots or root-suckers. A *simple coppice* is one none of the trees of which are selected to stand longer than one rotation, or where some are kept at the most to last through a second rotation; in a *coppice-under-standards* or *stored coppice*, on the other hand, certain trees called *standards* or *stores* are selected to

grow into larger timber trees, and may be kept standing through several rotations of coppice.

A forest *under conversion* is one the treatment of which is being gradually changed from the system of coppice to that of high forest.

A *wind-fall* is a tree which has fallen or has been felled by natural agency, as *e.g.* by wind.

A *wind-belt* is a belt of trees which is left growing thickly together, or has been grown specially to protect from the prevailing wind the crop growing behind it.

CHAPTER II

RELATIVE VALUE OF PURE AND MIXED CROPS

THE great advantage which pure crops have over mixed crops is that, especially if they are regular, they are much easier to work and easier to regenerate than those which are mixed. Even where they are irregular, there is not the necessity, which may often arise in mixed woods, of sacrificing a valuable tree for the sake of another of a still more valuable species.

Nevertheless, generally speaking, mixed crops are preferable to pure ones. The soil varies in composition, depth, and hygroscopicity from point to point, and thus also varies in its suitability to different species. Then, also, in a mixed forest the component species fit into each other more closely, and are able to protect and improve the soil to a greater degree than in a pure crop where all the trees have the same requirements and habit. Especially in the case where the principal species is shade-avoiding, it is necessary to have in mixture some shade-enduring species, which are soil-improving and can fill up the interstices in the leaf-canopy, or exist under the cover of the shade-avoiding trees. No doubt in the early stages of growth the struggle for existence is more complex; the principal species may be shade-avoiding, and becomes easily dominated and finally suppressed by other less valuable species, and it is necessary to carry out sometimes often-recurring operations in order to keep their crowns free. In the same way regeneration fellings are almost

always more difficult to carry out, as the shade-enduring species spring up and cover the ground with more alacrity when the first thinning out of the leaf-canopy is made. However, these disadvantages are usually more than counterbalanced by the generally more healthy character of the forest, and the most undesirable type of crop is that which is pure and entirely composed of shade-avoiding species. In such a forest the trees are not apt to develop clean boles, and the trees, especially in their later stages, will not be as healthy and vigorous as those which can have their boles protected from the sun and the soil over their roots kept shaded and moist by other species in mixture. All pure crops are also more liable to suffer from ravages of insects or from the spread of fungoid diseases, which often show a predilection for particular kinds of trees. Perhaps the next most dangerously situated in this respect is a mixed forest composed of trees belonging to the same natural order, as many insects or fungi, although avoiding trees belonging to other families, will thrive on allied species.

The maintenance of pure crops is considered justifiable only if the species composing them is a soil-improver, or if the soil is of such a natural depth and fertility and has a sufficient moisture not to deteriorate under it, or where the soil will only bear one particular species of trees; or, again, where only one particular species is of value to the proprietor; or, finally, where the rotation is so short that the effect of want of mixture on the leaf-canopy and in the soil has not had time to make itself felt.

In the Tropics there are several instances of naturally pure forests, such as those formed by some species of Dipterocarps, such as *Shorea robusta*, *Dipterocarpus turbinatus*, or by various kinds of *Acacia*. In the former case the gregarious nature of the trees is largely due to their shade-enduring character and the great height which they attain, from which they are able to suppress most competitors. In the case of the Acacias, they are the survivals of the fittest on certain soils.

For example, *Acacia arabica* will grow on low shelving banks of rivers on heavy soil which is periodically flooded, but *A. planifrons* in Southern India and *A. Verek* in the Sudan on poor sandy soil, and *A. tortilis* on sandy soil in arid localities. *A. Seyal* will thrive on black cotton soil with a moderate rainfall, and *A. mellifera* on similar soil with perhaps a certain admixture of salt, while *A. Suma*, or in places *A. Seyal* var. *Fistula*, will be found forming pure crops in clayey depressions. But, more commonly in the Tropics, and especially in regions of abundant rainfall, most of the forests are composed of mixed crops.

Although, in the descriptions of forests given in the first part of this volume, the names of mostly valuable species were given, it is unfortunately the case that in many places these valuable species are in a distinctly small proportion among the number of species which compose the crop, some of which are of no immediate value to the owner of the forest, nor likely to be of much value for some time to come. In some cases this small proportion is due to the shade-avoiding nature of the more valuable trees, owing to which their number has been gradually reduced by suppression; or it may be due to a lesser resistance to forest fires, or still more commonly to indiscriminate fellings, by which most of the valuable species have been eliminated and further reproduction made impossible.

The problem which the forester has to solve, both in the creation of new crops and in the maintenance and regeneration of existing forests, is how to obtain a proper composition of species so as to reach the maximum of utility for the owner. It is necessary that the species grown in the forest should all be suited to the locality, and that they should interfere with each other as little as possible. There should be, if possible, a suitable mixture of shade-bearing and shade-avoiding species, the former being in preponderance, especially in the early stages, as they are more soil-improving. In the creation of pure crops the chief consideration will be

that the species selected be suited to the soil and locality, and to the climate, and also that, if the seed is perishable, it can be obtained in a sufficiently fresh condition to be able to produce healthy seedlings. Before embarking on large enterprises, therefore, it is highly advisable not only to study the requirements of the species which it is desired to introduce, but also the meteorological statistics of the locality, as the neglect of this may lead to a useless expenditure of time and money.

We shall now proceed to examine the different operations which may have to be carried out either in the creation or regeneration of woodland crops, dividing these into two broad sections dealing with *artificial* and *natural* regeneration respectively.

While the systems of natural regeneration are used to obtain a new crop of trees either from the natural fall of seed from parent trees standing on or near the area, or from stool-shoots or root-suckers sprung from stools or roots of trees felled on this area, artificial regeneration is employed either for creating new crops on areas not previously covered with forest, or for altering the character of the crop by introducing new species, or for accelerating or assisting, or even replacing, the slower process of natural regeneration. This may be effected either with the help of seed or with that of shoots, such as slips, layers, or rhizomes.

Thus, natural regeneration subdivides itself into *regeneration by coppice* and *natural regeneration by seed*, the former being obtained from stool-shoots or root-suckers, or (in the case of bamboos) from culms. Natural regeneration by seed is effected by letting in the light on the area to be reafforested, either suddenly, by making *clear-fellings*, or gradually, with the help of *partial-fellings*.

Artificial regeneration is divided broadly into *direct sowing* and *planting*—that is, it can be obtained either by sowing the seed direct on the area on which the crop is destined to develop into forest trees, or by putting

slips or rhizomes direct on this area, or by layering on the spot from trees standing on the area; or the seeds, etc., may be raised first in a nursery, whence they are transplanted into the field.

But before these operations can be carried into effect it is necessary to collect the seed, test it, and prepare it so as to be ready for sowing. Even where direct sowings are effected it is necessary to establish nurseries in order to fill in vacancies where the seed has not come up. Also, before either seed or transplants can be put into the field, it is necessary to carry out some preliminary operations in order to secure the success of the young crop. These operations will vary according to the nature of the soil and locality and the species to be raised.

CHAPTER III

ARTIFICIAL REGENERATION: COLLECTION, TESTING, AND TREATMENT OF SEED

SEED may be obtained either by purchase or by collection in the forest. In the former case the seed should be obtained, by preference, from a trustworthy seedsman, and if it is of a perishable nature, and especially if it has to be obtained from a distant source, it should be purchased only under guarantee from the seller that a certain percentage of the seed will germinate. As an example of this may be quoted the case of the Para-rubber tree (*Hevea braziliensis*), the seed of which is apt to germinate and go bad while in transit, also various oily or very small seeds or others which quickly deteriorate. These have to be packed with particular care, such as in powdered charcoal or sawdust, and must reach their destination as quickly as possible.

When collecting the seed in the forest it is desirable to select sound trees in full vigour of growth. Unsound trees or those which have twisted fibre may transmit their inherent defects to their progeny; trees which are too young may have weak seed, and so may old trees, and a large percentage of it may be barren; it is also preferable to gather from trees sprung direct from seed rather than from stool-shoots. It is not advisable to collect the seed before it is ripe; but, on the other hand, especially if it be quickly perishable or small, or if it may be scattered by the wind or by the bursting of seed capsules, it is risky to wait too long.

The most common method of collecting is that of gathering fallen seed from under the parent tree. The ground should first be cleared of leaves and twigs from under the crown of the trees from which it is desired to obtain it, and that which first falls may also be swept away, as it is likely to be mostly barren. The fall of the seed may be assisted by shaking the branches. This method of collection is usual when the seed is heavy and likely to fall down straight. In the case of trees having winged fruit the collection must be made a little farther afield, or the fruit may be taken straight off the tree. The collection direct from the tree has also to be done with small seed or with that which, being contained within capsules which burst on ripening, is likely to be scattered far and wide. This should be collected just before the capsule is on the point of bursting.

In collecting seed off the branches of a tree, branches or masses of foliage should not be broken or lopped off, unless the tree is shortly to be felled. Where the seed cannot be plucked with the hand, a hooked stick may be used, the branches being, by preference, pulled upwards by a man standing at the junction of branches and stem. This reduces the risk of the branches getting torn off. A number of other implements are used for this purpose. Such are the pruning-hook, having two cutting edges (Fig. 16, *a*, *a*), with the help of which a cut may be given either upwards or downwards; the tree-pruner (Fig. 17); or, especially for large fruit, a device may be employed as with the mango gatherers of the Bombay Presidency[1] (Fig. 18). Two curved sticks are so tied at the top of a pole that in the middle they are far enough apart to admit of their being slipped over the fruit, after which the stalk is drawn towards the upper end of the space and then easily broken off by a twist of the hand. It may be useful to attach a bag to this implement, and this will save the labour of collecting from the ground; but it must be remembered that a weight carried at the end of

[1] Fernandez, *Manual of Sylviculture.*

a long pole soon tires the arms of the collector and makes the plucking slower. If the seed is heavy or likely to be injured by its fall, it is best to let it drop into a sheet held up at the corners.

When bamboo seeds it dies, and the best way of collecting is in cutting down the seed-bearing culms when the seed is ripe.

When the seed has been collected it should be subjected to a preliminary examination in order to

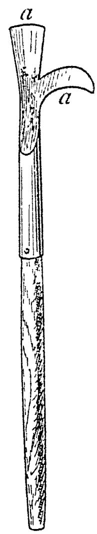


FIG. 16.

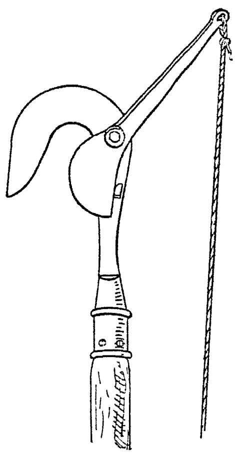


FIG. 17.

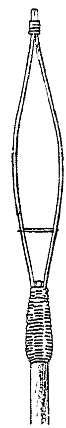


FIG. 18.

reject at once all that is visibly unsound or immature. It is also necessary, in the case of certain species, to give them a preliminary manipulation. Some kinds of seeds will still be enclosed within their capsules and must be extracted, or they are enclosed in fleshy pulp, or they may have wings which take up a lot of unnecessary room.

As regards those enclosed in dehiscent pods or capsules, a practical way of shelling them is to spread them on a piece of hard smooth ground, or if they are small on a sheet, in the sun, which will soon burst the

seed-pods. In the case of very light seed it is advisable to select a place sheltered from the wind. This method may be employed with most of the Leguminosae, the Bignoniaceae, the Asclepiadeae, several species of the Apocynaceae, Meliaceae, Malvaceae, etc.

Pulpy fruit can be collected in heaps, and when the pulp begins to rot it can be washed off in tubs of water. Winged fruit and winged seed are often delicate and cannot stand rough treatment, but where the wings are large and take up a lot of room, as *e.g.* in the case of the fruit of *Dipterocarpus*, these wings may be cut off.

In the case of oily or moist seed, it should be spread out in an airy and sunny place, and turned over with a rake twice or three times daily. This should be continued as long as is required, the duration of the treatment and the number of times the raking is applied daily depending on the kind of seed, the dryness of the atmosphere, and the temperature of the air.

Before spending time and labour in storing and sowing seed, it is advisable to thoroughly test it, and if a considerable percentage turns out to be barren or unsound, to reject it. A preliminary examination having already been made, a certain number of seed should be examined more carefully; this is done not only in examining the outside, but also by cutting a number open and examining the inside for traces of fermentation or attacks by fungi or insects. The plumule should be sound and the colour healthy, and no unpleasant smell of rancid oil should be emitted. If this examination turns out satisfactory, and a fair percentage appears to be healthy, it may be desirable, especially in the case of small seed, which is not always easy to examine, to find out what percentage of the seed will germinate.

This germination test can be carried on in various ways, the simplest of which is in sowing a known number of seeds in garden beds, or in pots containing either ordinary soil or sawdust or charcoal, and seeing how many germinate.

Special trays made of porous earthenware are also made for the purpose of testing the germination of seed. These trays contain depressions into which the seeds are put, either singly or several together, and which are kept constantly moist by water poured into a reservoir in the tray, or in a dish in which the tray

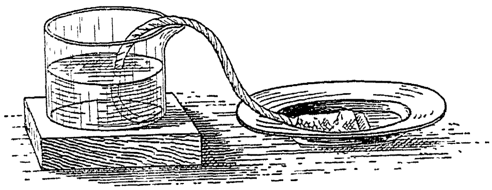


FIG. 19.

stands, from which it percolates to the depressions. The tray should be placed in a sufficiently warm place to stimulate germination.

Where these special trays are not readily obtainable the tests can be made just as effectively by placing the seed between two layers of wet flannel which are kept at an even temperature. The flannel may be kept wet by repeated sprinkling, but it is safer to provide a continuous supply of moisture by placing the flannel in a dish and connecting it with a bowl of water by means of a wet skein of wool, which acts as a syphon (Fig. 19); or, again, by tying the wet flannel to a wet skein and suspending it in a jar containing water, sufficiently near to the surface to be kept moist by capillary attraction (Fig. 20).

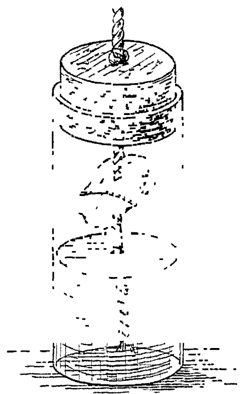


FIG. 20.

Certain seeds take long to germinate. This is the case chiefly with those which are enclosed within hard bony shells, such as Teak, or those which have a horny endosperm, such as several palms. It may be possible

to hasten the germination of these by soaking them in water for twenty-four hours, or by plunging them for a short time in hot water, or by filing one end (but this is risky); or the seed may be kept in moist heaps, when the heat produced by the beginning of fermentation may accelerate the appearance of the plumule. With Teak it is said that the lighting of a quick straw fire over some layers of seed will stimulate germination.

FIG. 21.—Filling a granary, Sudan. The roof is on the ground to the left.

But it is difficult to obtain a reliable test by these methods, and the eye-test may have to suffice.

In many parts of the Tropics, especially in those parts having a moist, continuously hot climate, the seed should be sown as soon after collection as possible. This applies most particularly to the perishable seeds, such as those which begin germinating before they drop from the tree or immediately after, as in the case of several Dipterocarps, or the Para-rubber tree, or those which are very small, or contain much moisture, or are

oily or resinous. These soon deteriorate in a tropical climate and should be sown as early as possible. Until they are used they should be kept in dry, cool, and well-aired places, preferably on trays and shelves.

There are others which, with due care, can be stored for a considerable period. These should be kept in cool, dry places, and sheltered from attacks of insects or rodents. In this case the seed may be stored by being hung in sacks or packed in cases with strong-smelling leaves to keep off insects, or in many cases the granaries made by the natives of the place may be the most convenient and effective method of storage (Fig. 21).

CHAPTER IV

NURSERIES

NURSERIES are of two kinds, *permanent* and *temporary*. The former are established in order to give a continuous supply of plants to a large area, and formed as near the centre of operations as possible. Temporary nurseries are only destined to supply plants for the area in their immediate vicinity, and they are abandoned as soon as this particular area is stocked.

While the latter save a great deal of labour and expenditure on transport of plants to the field, especially in a hilly country, and are also less costly, the former will, as a rule, supply stronger transplants, owing to the greater amount of attention that can be given to them. In flat countries with easy road or water transport, therefore, or in those where there is a difficulty in obtaining a water-supply for watering the seedlings, or where the supervision or protection of outlying nurseries is difficult, it will be preferable to establish permanent nurseries if the supply has to be continuous.

The principles to be followed in either case are the same, viz. a site as near the centre of operations as possible, soil and locality suitable for raising the seedlings, a compact shape, and adequacy of water-supply.

On permanent nurseries, however, works are made on a more lasting and therefore costly scale, and, as seedlings are raised year after year on the same area, the beds require manure from time to time.

In selecting a site for a nursery, not only should

it be near the centre of operations, but it should be on fairly level ground, and it should have soil of good average quality, a sandy loam being the best. In permanent nurseries the quality and texture of the soil may be improved by addition of sandy soil where it is too stiff, and of loam where it is too light, but in temporary nurseries this is rarely possible, and the selection should be carefully made.

The site should not be on water-logged soil, but it should be within easy reach of water either from a watercourse or by sinking wells. In places with a regular, evenly distributed rainfall this may be of less importance for temporary nurseries, but even there it is desirable.

The nursery should also be in as sheltered a position as possible, where it will not be exposed to violent winds, nor, in hot dry countries, on the most sunny aspects, nor, at higher elevations, where frosts occur in the cold weather, either in damp hollows or on easterly aspects, where tender shoots are apt to become frost-bitten.

The shape of the nursery should be compact; as near the shape of a square as possible is the best for supervision, working, and fitting in the beds. The area will depend not only on the number of seedlings which will have to be raised, but also on the species, as some kinds take up more room than others, and also on the size which the seedlings are to attain before they are put out in the field. In the nurseries where *nursery lines* are made (*i.e.* beds into which the seedlings are transplanted before being finally lifted for transport to the field), an additional area will be required. In permanent nurseries it may be desirable to let a certain proportion of seed-beds lie fallow after having been worked for a year or two. In this case, also, the size of the nursery will have to be made sufficiently large to admit of this being done.

The nature of the fence put round a nursery will depend on the class to which it belongs, its situation,

.nger which it may be exposed to
imals.

ıent nursery it may be advantageous
wall, which will keep out all animals
r it may be sufficient to erect a wire
our strands, whether barbed or not.
nce, preferably composed of thorny
so as to make it impenetrable, will
ermanent and in temporary nurseries
cupines are abundant the fence must
ble for them. The cheapest will be
ch will also keep out small deer or
takes are easily obtainable, a stockade
id the nursery, consisting of posts of
ording to the animals which have to
the case of elephants the stockade
d may have to be strengthened by
n the *inside* of the stockade, and a
ve to be made on the outside.

oed wire of at least four strands will
the larger animals. Even elephants
ı contact with it. It may be of
ce the strands more visible by means
n happens that pigs, deer, or antelope
to a wire fence and sometimes break
r animals will hop through the strands
ıem, and wire netting is required in
the nursery contains such plants as
wire netting is particularly necessary,
great attraction for hares, porcupines,
es, which not only eat the shoots but
c of larger plants. In such places, the
ıld not merely be pegged to the ground,
ık into the ground with the lower edge

changing a nursery should be cut down.
would give a certain amount of shelter
dlings, the cover would, in many cases,
l, and, especially in a country having

tropical downpours of rain, the drip from the crown would bruise delicate plants.

The soil of the nursery should be first worked up and cleared of stumps, stones, and roots. The depth to which it will be turned up will depend greatly on whether the seedlings are intended to develop a deep rooting apparatus, and also on the nature of the soil and the species to be raised. The beds are made rectangular, of convenient lengths, and of such a width that the middle can be reached by the hand from either side of the bed without it becoming necessary to trample on it when working in the middle. This means that the beds should not be much over one metre (say 3 ft.) wide.

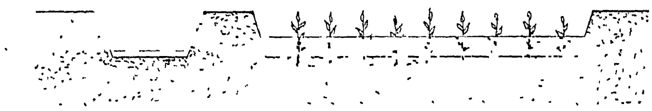
Paths should be made, on either side of the beds, of sufficient width to provide for the necessary traffic without risk of injury to the plants in the beds; and in large nurseries, broader roads, capable of admitting wheeled traffic, or possibly tramway lines, will have to be made at convenient distances and in the most suitable directions. It will be convenient to make channels to carry the water to the beds alongside the roads and paths, the chief channels running alongside the main roads. In some places, especially in temporary nurseries, the channels between the beds may combine the duty of paths when they do not carry water.

The water may be supplied to the beds either by *flooding* them or by *percolation* (Fig. 22). Flooding is the favourite system of irrigation by natives of the Tropics, at least in the Old World. The beds are made flat, and so constructed that when water is let in from the channels it covers the whole surface uniformly. The water is let in either by a stroke of the hoe which opens a passage from the channel to the bed, or, where the channel is either lined with stones, tiles, or cement, or carried in pipes, an opening of a more permanent nature is made. This can be closed by means of a board or sheet of iron or, in the case of pipes, by a tap.

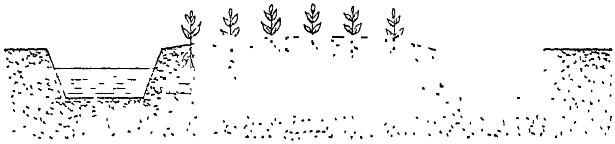
When seed-beds are watered by percolation, *i.e.* by the infiltration of water from water-channels, these are

made to run in the best manner possible to secure this infiltration, and either a continuous stream of water must be kept running or the channels are blocked at the lower end until they are filled to the required height. The water is then allowed to stand until it has had time to soak in, when the remainder is allowed to flow off. The proper degree of saturation can be more quickly obtained when the water is made to meander in the beds, as *e.g.* is shown in Fig. 23.

Beds irrigated by flooding must be level. If the nursery is on a slope, the beds must be terraced. With irrigation by percolation, level beds are preferable, but a



Cross-section of a seed-bed irrigated by flooding



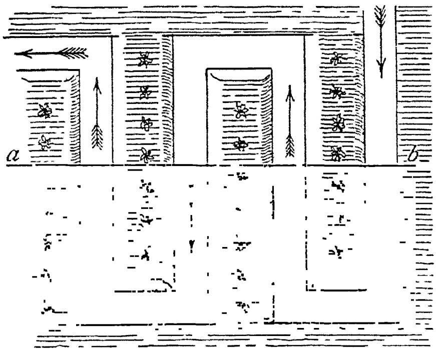
Cross-section of a seed-bed irrigated by percolation

FIG. 22.

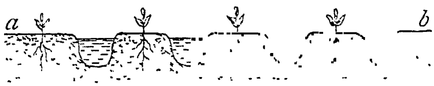
slight slope may be allowed. In this case the length of the beds should be at right angles to the slope, and the channels should either be constructed along the upper edge or they should be made to meander through in the manner indicated above. Even beds which are only irrigated by the natural fall of rain should be made at right angles to a slope, especially in tropical countries, where rain falls heavily and there is danger of scour. If the beds are made as indicated, the paths between them can act as drains, to a certain extent at least, and check the rush of water from a tropical downpour.

The choice of the flooding method of irrigation will depend on the soil and on the species to be raised; but,

generally speaking, with a fairly porous soil, such as should be obtained for a nursery, the percolation method is preferable. In a bed watered by flooding there is, near the inlet of water, not only a greater rush, but also a certain deposit of silt, especially if the water is at all turbid, and tender seedlings are apt to be bent down and even covered up. The whole bed is also apt to be covered by a thin, almost impermeable layer of silt, which excludes air and has to be constantly broken up.



Plan and



length-section of portion of a seed-bed irrigated by a meandering channel.

FIG. 23.

With the other method only the sides of the channels have to be scraped with a hoe from time to time, and there is no risk of the seedlings being injured either by rush of water and silt or by the hoe.

The water for irrigation has to be obtained either by leading it by means of pipes or canals from a neighbouring spring or watercourse or tank above the level of the nursery, or by lifting it from a well or from a tank, lake, or watercourse below its level. The best source of supply is a perennial stream or lake, tapped at a point higher than the

nursery, and not too far from it. The distance from which it will pay to bring water will depend on the nature and size of the nursery, and on the other means of obtaining a water-supply. Where the supply of running water is not constant it may be necessary to construct a storage tank in the upper part of or above the nursery. A supply of water may also be obtained by damming a watercourse or depression, and thus forming a reservoir which becomes filled during the rainy weather. It must be remembered, however, that in the Tropics such reservoirs breed millions of mosquitoes, which may become a source of danger to the health of the establishment. It is, therefore, preferable to have sheets of standing water at some distance. For the same reason puddles in the channels or in any part of the grounds should not be allowed, and tanks should be covered up with wire gauze of sufficiently fine mesh to prevent the access of mosquitoes to the water.

If the water has to be lifted, a multitude of means may be employed. In large permanent nurseries the most effective and, in the long run, probably the cheapest is the setting up of a pump worked by an engine which can be driven by steam or petrol according to the cost of fuel obtainable. The power of the engine and diameter of the suction-pipe of the pump will depend on the area to be irrigated. Information on this point can be readily obtained from manufacturers. For smaller areas, pumps worked by draught animals or by men can be set up, or, where the wind blows steadily during the greater part of the year, the pump may be worked by a windmill. For sending up water from a sheet of water to a high bank forcing pumps are also useful.

Where these more compact machines are not readily obtainable it may be advantageous to utilise some of the methods employed by the natives of the country or in other countries. One of the simplest is the *shadoof*, which is employed not only in Egypt and India, but also in parts of Southern Europe. It consists of a long

yard or arm fixed below the middle to a horizontal cross-piece supported at either end by uprights made of timber, mud, or masonry. At the end of the longer portion of the yard hangs a bucket from a length of rope which is sometimes stiffened below by a piece of stick, while a counter-weight of stones or mud is attached to the shorter end. The end with the bucket is lowered into the water and is then either jerked up to the necessary height, partly with the help of the counter-weight and partly by a pull on the rope, or, in

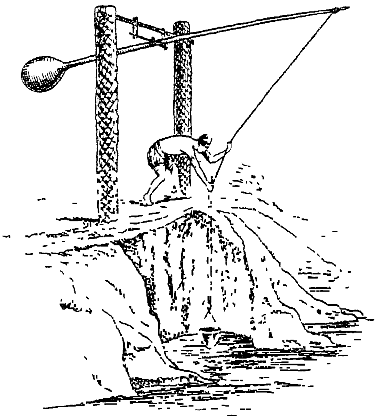


FIG. 24.

certain places, by a person walking to and fro on the top of the yard. The length of the yard will depend on the height to which the water will have to be raised. In a narrow well it is not possible to go deep with a shadoof, as the vessel containing the water would hit against the sides and spill it. The Egyptian shadoof (Fig. 24) is usually comparatively short. If the lift up the bank of the Nile is too high for one shadoof, there will sometimes be two or three superposed. This method of irrigation will only do for small areas of about 1 hectare or less (2 acres).

For higher lifts one of the most common methods of raising the water is with the Persian wheel or *sakia*,

which is employed almost everywhere where the shadoof is found. The groan of the sakia is one of the most familiar sounds on the banks of the Nile. The sakia is usually worked by bullocks or other draught animals, but where the current is strong enough the latter is used as motive power.

The most common pattern of sakia consists of a large cogged drum placed over the mouth of a well or overhanging a bank, bearing an endless rope to which, at distances apart, earthenware or tin vessels are attached,

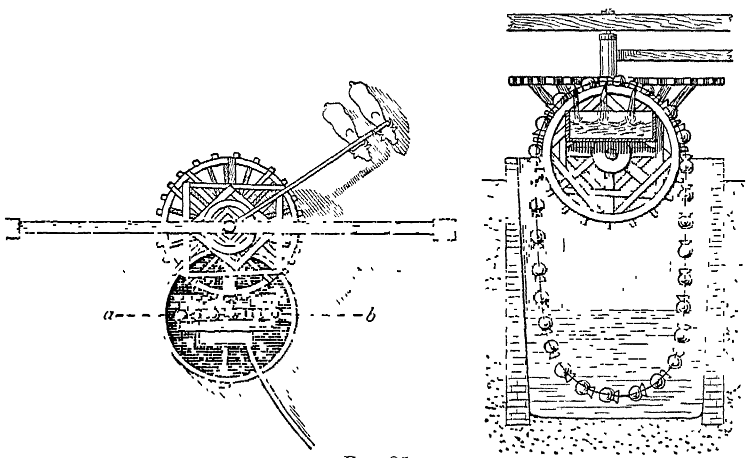


FIG. 25.

which each in turn scoop up the water and bring it to the top of the drum, where it is poured into a trough whence it is led away. The distances between the vessels will depend on the height of the lift; with a high lift a large number of vessels filled with water would be too heavy to raise. The drum is set in motion by a cogged wheel revolving horizontally and turned by means of a lever by a pair of oxen. Fig. 25 shows one type of sakia, but in Egypt, where the drum is usually thrust out as far as possible to be well clear of the bank, the latter does not bear the cogs, but they are placed on a cogged wheel at the end of the extended axle of the drum. This axle is extended horizontally

close above ground level, sufficiently far to enable the bullocks in circling round the two cog-wheels to have room, in stepping over the axle, to pass between them and the drum. Iron sakias, which are easier to work, are also made by European manufacturers; but they should not be used unless the services of a blacksmith are readily obtainable. In Lower Egypt, in the Delta, where the lift is not high, the string of buckets is dispensed with. The rim of the drum is made hollow and

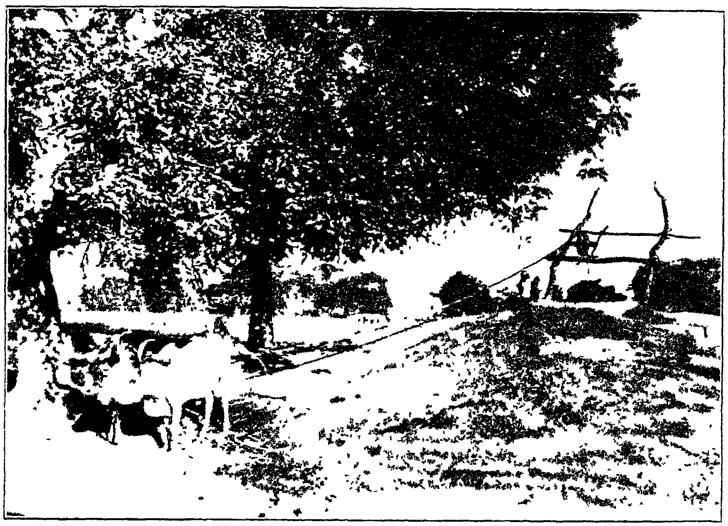


FIG. 26.—Charas, Bombay Presidency.

subdivided into compartments which are filled when the wheel dips into the water, and empty by a side opening when each compartment reaches the top. These wheels or drums are of greater diameter than those of ordinary sakias. One sakia is usually considered equal to the task of irrigating about 3 hectares (7 acres).

Wheels made to lift water by means of the current are not unlike an overshot wheel furnished with paddles. They are made of various diameters according to the height of the lift and strength of the current. One of the features of Verona is the number of these huge

wheels, moved by the current of the Adige, which raise the water to a height of 6 or 7 metres. They are also used in Egypt, and also in Mesopotamia, where they go by the name of "Naoura."

For shallow lifts the *Archimedean screw* is much used in the Nile Delta, while for raising water from deep wells the *Charas* is largely employed in India. This consists of a large leather bag attached to a rope passing over a pulley placed across the mouth of the

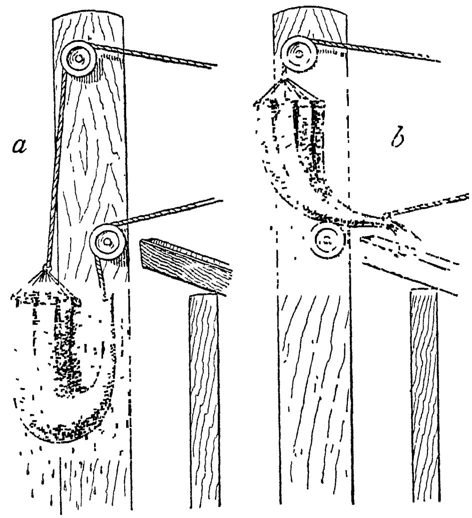


FIG. 27.

well. The rope is hauled in by bullocks walking down an inclined plane (Fig. 26), and the water is emptied from the bag into a receiving trough by a man who stands at the mouth of the well. In some parts of India an improved Charas is made which does away with the necessity of keeping a man at the mouth of the well. The leather bag is made horn-shaped and has two openings, one at the wider end to take in the water and one at the pointed end to pour it out. Each end of the bag is attached to a separate rope, and each rope passes over its own pulley, that connected with the

pointed end being lower than the other pulley by nearly the length of the bag. The two ropes are joined together at a convenient distance, and when the bag is raised the larger end is hauled up to the level of the upper pulley, while the lower end, which now acts as spout, is drawn over the lower pulley and discharges the water (Fig. 27).

Where the supply of water is some distance away, and bullock, mule, or donkey transport is cheap, it may be advantageous to bring the water in leather or canvas bags slung in pairs across the backs of these animals, or, if wheeled traffic is possible, by means of water-carts. There are numerous other ways of lifting water, especially where the lift is slight, such as a canoe-shaped trough, set up like a see-saw, which is used in Ceylon rice-fields, scoops, etc.

The seed is sown in the beds in parallel rows, usually across the width of the beds. It is usually put in at a depth about equal to the thickness of the individual seeds. They can be put in to the required depth if they are large, either by pricking holes in the soil with the finger, or with a wooden or metal implement; or a furrow is made with the help of the trowel-hoe (Fig. 28) or, especially for small or moderate-sized seeds, with a furrow-board or wedge-board. Figs. 29 and 30 illustrate two kinds of such boards and of the impressions made by them on the soil of a seed-bed. For larger seeds a single wedge is also sometimes used. Certain kinds of seeds, which are not to be allowed to stand in too moist a soil, have to be sown on ridges, and the seed-bed is divided into ridges either by means of a hoe, as *e.g.* when water-channels have to meander through the seed-bed for percolation, as indicated above, or with the ridge mould (Fig. 31). After the seeds are put in they should be lightly covered with earth.

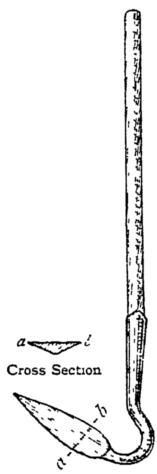


FIG. 28.

With very small seeds the covering should be just thick enough not to be washed away by the first rain or blown away by the wind.

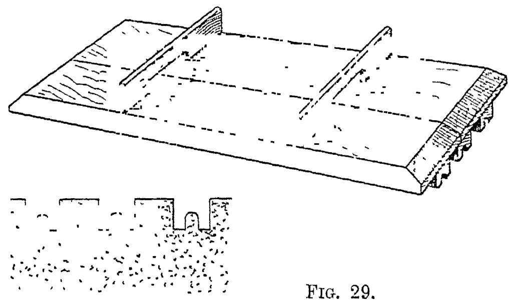


FIG. 29.

With seedlings which do not bear transplanting well it is best to sow their seed in small, loosely woven baskets,

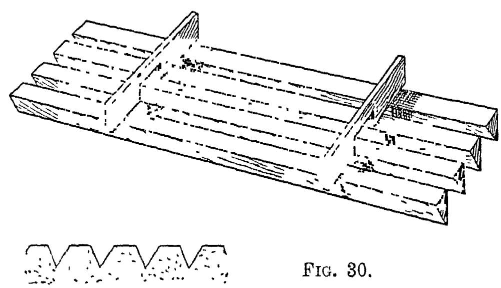


FIG. 30.

called "supply-baskets" by Ceylon planters. These are usually made of a roughly conical shape of split

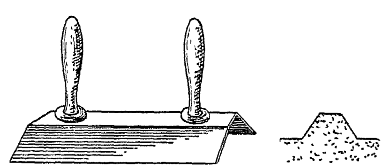


FIG. 31.

bamboo, if obtainable, or else of split reeds, canes, or of withes. When the transplants are taken into the field, they are carried, basket and all, and only the

bottom cut open before being put into the ground. With a little practice supply-baskets can be made quickly and cheaply. If I remember rightly, in Ceylon they cost about Rs. 5 (6s. 8d.) per 1000.

Certain seeds germinate with difficulty in a seed-bed, or take a long time to germinate. For example, this is often the case with teak seed, which may take as long as two years to push forth its radicle, and this is also the case with Ceara-rubber (*Manihot Glaziovii*). Our knowledge of the best methods of hastening germination is as yet very incomplete. In some cases it has been found that seed which has been stored for one year germinates much more freely than fresh seed. In others soaking the seed in cold, or more or less warm, water for twenty-four hours assists germination. Or it may be piled in moist heaps or kept moist in pits for a longer or shorter period, when the moist heat thus engendered causes it to germinate. With teak one of the methods successfully employed consists in spreading the seed on the ground in layers about 10 cm. (4 in.) thick, and watering constantly, and from the third day the individual seeds which have started germination can be picked out and put into the seed-beds. Another somewhat similar method consists in putting the seed in layers about 2½ cm. (1 in.) thick in a pit 3 metres (10 ft.) square and 45 to 60 cm. (18 in. to 2 ft.) deep, with alternate layers of earth of the same thickness, up to the brim of the pit, and in flooding, on alternate days, five times. After this the whole mass is thoroughly mixed and watered again on alternate days until germination sets in.[1] It has also been said that a light grass fire set alight over a layer of teak seeds assists germination.

It may also happen that delay in germination may be due to a too great or too small supply of moisture, to too heavy a soil, or to too little shading. Where previous knowledge has not been acquired regarding the germination of certain seeds sown, and it turns out that they do

[1] R. S. Pearson, in *Indian Forester*, vol. xxxi. No. 3.

not readily germinate in ordinary seed-beds, experiments should be made, if possible, on soil similar to that on which the species grows in its natural habitat, and in circumstances similar; *e.g.* if it is found growing under cover on well-drained quartzitic soil, the seed should be sown on ridges of sandy soil, lightly shaded over.

The amount of watering to be given to seed-beds until the seed germinates will depend on species, soil, and climate. Many species will not germinate freely if the soil is too moist, and it is better, as a general rule, to keep the soil only moderately moist. The same rule applies also to newly germinated seedlings which easily damp off. Before germination, unless the soil is very porous and dries easily or cracks on the surface, it is not usually necessary to water every day; unless a light sprinkling with a watering-rose be given. After germination it may become necessary or desirable to water as many times as thrice a day. If given only once, the evening is the best time for watering, except in localities and at seasons where frosts occur, where plants watered in the evening are more likely to suffer from frost-bite. In such places the watering should be done in the early morning; if done in the middle of the day the seedlings may suffer from over-transpiration.

The shading of young seedlings in the seed-beds is a necessary item in the management of nurseries. In permanent nurseries light mats made of straw, or in some cases of open-meshed coco-nut matting, are usually kept and placed on supports sufficiently high over the beds to admit of the circulation of air and the admission of a certain amount of light. In frosty localities, where the early sun has to be feared and wherever the slanting rays of the sun are too strong, other mats are also placed vertically along the sides of the beds. The mats should be removed when the sun is not too strong, except where frosts occur, when they should be put on overnight. In temporary nurseries, mats can be roughly made of grass or twigs, or it may suffice to stick leafy boughs into the ground to give the necessary shelter.

In such a case care should be taken to select the twigs only of such plants as have leaves which do not easily drop off and injure the seedlings by falling and decaying on them. Tender shoots which easily droop should also be avoided. In places where the *Gleichenia* fern is to be found, its fronds make an excellent light shelter; they should be stuck all over the bed, but not so densely as to shut out light and air. The bracken fern (*Pteris aquilina*) also does fairly well, but not so well.

The beds should be kept carefully weeded and the surface should be kept sufficiently loose to admit the access of air to the roots. In breaking up the surface care has to be taken not to injure the seedlings. The weeding should be done frequently, and at the same time, if seedlings come up too thickly in the beds, they should be carefully thinned out. The weeding can be done with the hand, or with an implement such as a weeding-fork (Fig. 32), or a knife, or, when the seedlings are in rows sufficiently far apart, with a Dutch hoe (Fig. 33); but with natives who prefer doing their work squatting, a long-handled tool like the last would not be popular. They will even prefer a short length of hoop-iron with a piece of rag wrapped round one end.

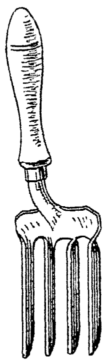


FIG. 32.

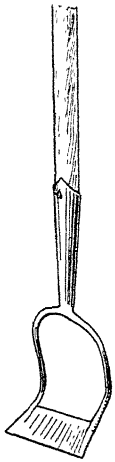


FIG. 33.

In the case where seedlings are taken direct from the seed-bed to the field, and before being transplanted are allowed to attain a certain size, it may be desirable to carry out pruning of the taproot sometimes before the moment for transplanting has arrived. In order to disturb the seedlings as little as possible, the cutting back of the taproot is done, without lifting them, by means of a spade with an oblique cutting edge which

will easily cut through the root. There are several species, however, which cannot bear this mutilation, and these should either be transplanted into nursery lines as soon as it can be done safely, or they should be raised in baskets, or the seed-bed should be made with a hard bottom which will arrest the lengthening of the taproot. In places where termites abound the cutting of the taproot may also be a risky operation, as white ants at once attack the wounded portion; in damp, hot climates, which favour the development of fungi, which penetrate into plants through any wounds they may have received, the same remark applies.

Nursery-lines are beds, within the nursery, into which seedlings are transplanted from the seed-beds, in order to allow them more growing room and to develop a good tuft of roots, and also to accustom the seedlings to transplanting by placing them first in a place where they will still have constant supervision and care. In many cases nursery-lines are dispensed with altogether, but if the species are delicate it may be necessary to have them. The transplanting into these lines is usually done only once, but it may have to be done twice or, rarely, three times. Transplants which are first put into nursery-lines are usually stronger than those which are put out direct into the field; on the other hand, the cost of production is considerably enhanced.

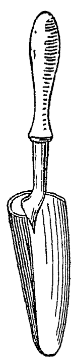


FIG. 34.

When taking the seedlings from the seed-beds, they may be conveniently lifted, if small, with an ordinary garden-trowel (Fig. 34). They should be taken up, if possible, with earth round their roots. If taken up without earth care should be taken not to forcibly remove all particles of earth adhering to their roots, as this removal may lead to the breaking of tender root-fibres. The seedlings should also not be moved before they are lignified, as otherwise they are apt to wilt and die.

Larger seedlings are usually lifted with some sort of

spade or transplanter, or, if they are to be taken up without a ball of earth round their roots, with a fork.

In a nursery where lightness of transport is not usually a very great consideration it is usual to take up the seedlings with a ball of earth round the roots. It may, however, happen that this transport has to be considered, especially when the nursery is large and the transplants have to be taken to distant beds, or when it is on a hillside and they have to be carried up. In such a case the seedlings may be taken up without earth, care being taken to injure the root-system as little as possible, and to put in the plants into the nursery-lines without delay. The best implement is a three- or four-pronged fork (Fig. 35). The fork is driven into the soil behind the seedlings and the handle forced backwards. By this operation the prongs are driven upwards, and they lift the seedlings, which can be picked out. Schlich[1] recommends using two forks driven in on either side of a seedling, and the handles forced backwards and outwards, so that the prongs of the two forks meet and lift the seedling evenly.

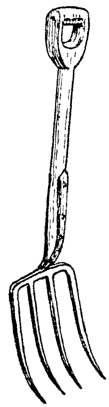


FIG. 35.

The same operation with a spade will bring up the seedlings with earth attached. When the seedlings to be lifted are close together, a very usual method of taking them up with earth attached is to dig a trench on one side of the seedlings, making the trench of about the same depth as that to which the roots penetrate: The spade is then inserted on the opposite side, the handle is forced backwards, and the blade of the spade lifts the seedlings with earth attached (Fig. 36). When the seedlings are more spaced they can be lifted by driving the spade on all sides of each individual plant and bringing it out with a lump of earth in the shape of an

[1] *Manual of Forestry*, vol. ii.

inverted pyramid or cone. With the flat spade (Figs.

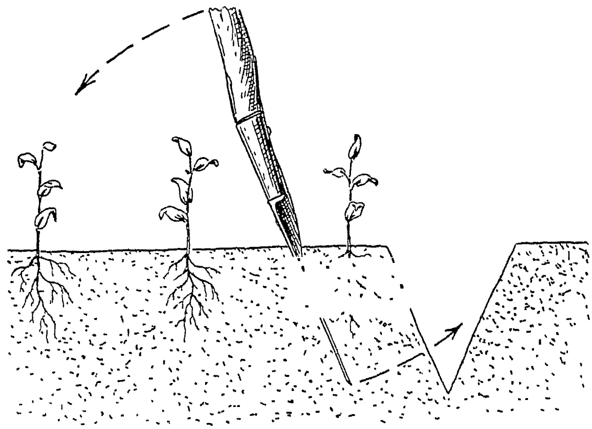


FIG. 36.

37 and 38) four incisions are required, and with the semicircular spade (Fig. 39) only two or three.

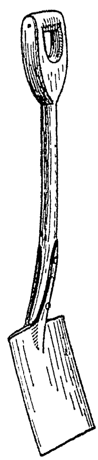


FIG. 37.

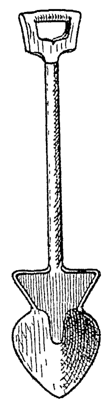


FIG. 38.

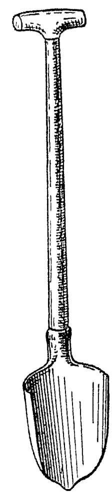


FIG. 39.

Another implement which is much in use for lifting plants is the circular transplanter (Fig. 40). The blade is in the shape of an inverted truncated cone, and is

provided with a slit in front to admit of passing in the stem of the seedling. The blade is then pressed down, and the plant is lifted with a cylindrical ball of earth attached to the roots. The diameter of the conical blade and its length must vary with the size of the transplants to be lifted and the length of the roots of the transplants. A somewhat similar implement, which was patented in Ceylon but the patent of which may have expired by now (Fig. 41), has the advantage, when

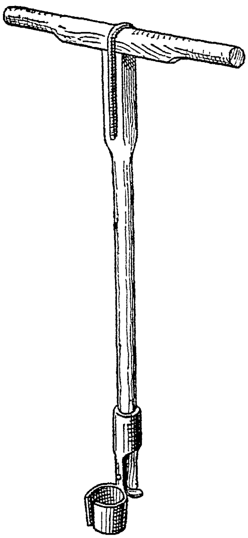


FIG. 40.

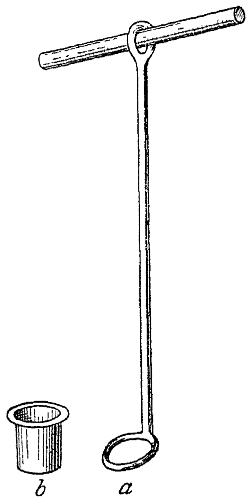


FIG. 41.

the soil is friable, of preventing the balls of earth from breaking up in transit. Here, instead of the conical blade of the circular transplanter, there is a stout iron ring (*a*), into which is fitted a cylinder made of tin (*b*). This takes the place of the blade and cuts into the soil round the seedling, which is then lifted. The plant with the cylinder still enclosing the root-system is then removed and set aside for transport, a new cylinder is fitted into the ring for the next plant, and so on. The cylinders are only removed from the balls of earth when

the plants are being put in again, and are then ready to be used again for other plants.

The soil should be watered a sufficient length of time before lifting the seedlings, so that it should be of the proper consistency, not too moist and not too dry, for getting the plants up without damage to the roots. Especially with a dry soil the root-hairs get easily torn, and that is particularly the case with seedlings lifted without balls of earth. When the soil is too moist the balls of earth are apt to drop away unless they are strongly compressed, in which case access of air to the roots is rendered more difficult and the plants are apt to rot.

The sooner the transplants are put in again after being lifted, the less likelihood will there be of their suffering from shock due to the transplanting. They should be kept cool until they are put in. Seedlings without balls of earth may be put into a basket with damp moss or grass and covered over with twigs or pieces of banana leaf. Those having balls of earth should be shaded over if they are likely to remain unplanted for any length of time.

The amount of space allowed to the transplants in the nursery-lines will depend on their size at the time of transplanting, on the size which they will be allowed to attain before they are again lifted, and on whether they are to be lifted with or without a ball of earth. If they are small, holes can be pricked out with the finger, or with a stake (Fig. 42), or with a garden-trowel, knotted lines with knots at the required distances being used to guide the nurseryman. For larger transplants pits or furrows may be made with the spade or hoe.

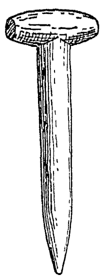


FIG. 42.

In putting in the transplants care should be taken to put the taproot straight down, as a twisted or bent root affects the future growth of the plants. The seedling should be held vertically with one hand, the root-system hanging straight down into the orifice made for

it. If the plant is small the insertion of finger, stake, or trowel into the earth on one side of the hole and pressure sideways towards the plant will suffice to secure the adhesion of the earth to the roots. With larger transplants the putting in of those with balls of earth is simple, as all there is to do is to keep them upright and to press in the earth of the bed all round firmly with the hand or foot. With ball-less transplants they are held in one hand while fine earth is shaken in round the roots, a slight shaking being at the same time given to the plants to make the particles of earth fit in better all round the roots and into the root-system. When this is done more earth may be scraped in and pressed down with the foot. It is advantageous, before putting these

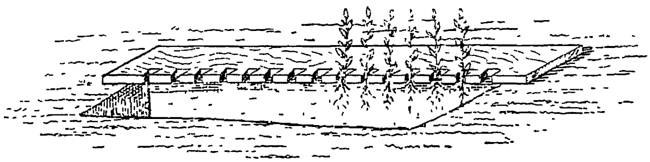


FIG. 43.

plants in, to dip the roots into a bucket of water or, better still, into light liquid manure.

When the transplants are put into furrows, it is usual to use a "planting board" (Fig. 43), which not only enables the nurseryman to use both his hands in putting in the earth, but also to cover the roots of several transplants at once. When planting into furrows with the help of the planting board, it is best to make one of the sides of the furrow vertical, as it not only helps in keeping the roots vertical, but it makes the filling in of earth easier. The board can also be used for planting in holes, a single transplant being put in a notch over the spot where it is to be planted. For larger transplants a clip or holder has been devised (Fig. 44),[1] which does away with the necessity of having two men, one for holding the plant and the other for

[1] After Schlich, in *Man. For.* vol. ii. p. 213.

putting in the earth. After the earth is put in it should be firmly pressed down. When there is any danger of the roots, under new conditions, being incapable of supplying the necessary amount of moisture to the leaves and tender parts, it is advisable to do a certain amount of pruning or even of cutting back or "*stumping*" the plant above the root-collum. This pruning or stumping is generally done at the time of transplanting, but it would probably be preferable to do it a day or two before. If the transplanting is done at a time when the seedling is leafless—and whenever possible this is the best time to do it—the pruning may be slight or altogether dispensed with. Water should be given to the transplants after they have been put in, but it should not be given too abundantly at first, so as not to produce excess transpiration. It should be just sufficient to make the particles of earth close in round the rootlets and form proper contact. Another watering may be given towards evening, except at times or places where a frost may be expected during the night. Subsequently, the nursery-lines may be watered in the same way as the seed-beds, and the shading and weeding should also be carried on in the same manner.

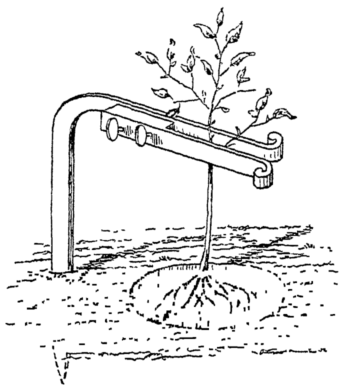


FIG. 44.

The raising of plants from *cuttings* is not usually done on a large scale for forest operations, and, when done, it is more often in the field than in the nursery. Not all trees can be successfully raised from cuttings, and those which can be raised in this manner are usually neither so well rooted nor so long lived as those obtained from seed. However, a large number of trees for avenues, *e.g. Albizzia Lebbek* and *Pithecolobium*

dulce, are raised in this manner; others, such as various species of *Erythrina*, are used for nurses, and the same or *Jatropha Curcas* or the Milk-hedge (*Euphorbia Tirucalli*) serve for live hedges, while the Ceara-rubber tree (*Manihot Glaziovii*) can also be raised in this way. Some of the Burseraceae, such as *Balsamodendron* and *Boswellia*, and several species of *Ficus* also spring readily from cuttings.

Some of these species will begin to sprout even when the cuttings are put in in the shape of large posts, and these should be put into the field direct, while others come up better from smaller and tenderer shoots, which, however, should be well lignified and healthy. The end to be put into the ground should be cut clean with a slanting cut, in order to give a large surface for absorbing moisture, while the upper end should be cut off square, and may be covered with a cap of clay to keep it live and moist. The cutting should be put in in a slanting direction, so that the underground portion may remain in the upper, better-aired layers of the soil. If the soil is not soft, a hole should be first made with a stake to prevent the bark being stripped off by friction. About two or three buds may be kept above the ground. It is best to cut off all the leaves whether above or below the ground. After the cutting is put in, the earth should be pressed home against it, and it should be watered. Where white ants are abundant, it is advantageous to raise cuttings in beds with cement floors.

Bamboos are sometimes raised from cuttings. These are usually obtained from the lower nodes of culms which are more apt to produce adventitious roots. One method, employed in Ceylon, consists of cutting off segments with a node at either end. A slit is made on one side on the internode, presumably to admit moisture and stimulate the production of adventitious roots (Fig. 45).

FIG. 45.

The cutting is laid horizontally and almost covered with earth, the slit being kept above the surface of the ground. The earth is pressed down and well watered. Sometimes the cuttings consist of several nodes, and are put in like other cuttings, one or two nodes being kept above ground.

Layers are not much in use for forest work, and, if used, they are more generally raised in the field on the spot where they are intended to grow into trees. But it may occur that they have to be raised in the nursery. The most usual method of layering consists in bending down the branch of a tree or a stool-shoot and of burying part of it underground in order to get roots to

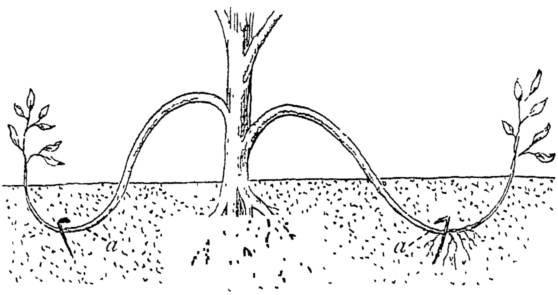


FIG. 46.

develop in that portion. Sometimes, if the branches are very elastic and the ground soft, it is necessary to peg them down (Fig. 46). All leaves should be stripped off except at the end of the shoot which appears again above ground. In order to stimulate the production of adventitious roots it is usual to cut a slight nick into the under side of the shoot, just above (*i.e.* in the direction of the parent tree) the place where it is intended that the roots shall appear (*a* on Fig. 46).

Another method of layering, called "pot-layering," is employed for branches which are either too high up a tree or too brittle to be bent into the ground. In this method the soil is held in position round the portion where it is intended that the roots shall spring, by

means of a pot split in two, or by a box, or by matting (Fig. 47). Here, again, the development of adventitious roots is encouraged, either by tying a ligament over the place where they are intended to come, or by removal of a ring of bark, or by cutting in on one side. The drawback of this method is that the soil is very apt to dry quickly, and that therefore it has to be constantly watered, either by hand or by suspending above it a pot of water with a small hole, or provided with a syphon, which will keep up a constant supply of moisture.

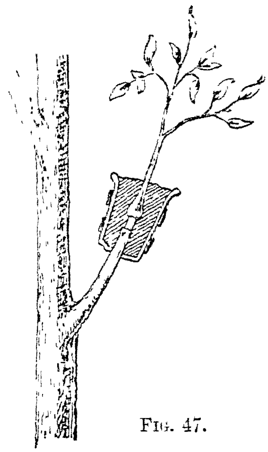


Fig. 47.

A method preferable to that of raising bamboos from cuttings is that of propagation from *rhizomes*. Seed is not always available, as the clumps only flower after intervals of several years, sometimes thirty to fifty. Bamboos raised from seed also take more years to come to exploitability than those raised from rhizomes. In this case rhizomes from a bamboo clump are removed, each with its culm, and put bodily into the ground. Those from young clumps are the best. If the culm is fully developed it is necessary to cut it back, leaving only three or four internodes above the ground.

The schooling of root-suckers in a nursery is not, as a rule, advisable in hot countries where fungoid diseases easily enter into the plant through the wound, or white ants attack them. Still, on occasions where seedlings may run short they may be used, but they are almost as likely to grow successfully if put out straight into the field.

Seedlings are sometimes taken from the forest and either put straight into the field or schooled in nursery-lines. They should be taken when still small, as their root-system is apt to develop irregularly in the forest and to get damaged by lifting.

However good the soil, there comes a time when permanent nurseries require manuring. It is usual to let a certain portion of the nursery lie fallow in its turn, and manures of various sorts may be applied, or leguminous crops can be cultivated on the area and then ploughed in; in fact, a permanent nursery has to be treated very much in the same way as field crops. In all nurseries, whether temporary or permanent, it is advisable to collect into a pit all leaves, twigs, and other vegetable débris which are swept in keeping the place clean. In hot and damp localities leaf-mould can usually be obtained from the bottom of the pit after two or three months; in drier countries some moisture may be added, liquid manure being the best, and the heap should be turned over from time to time in order to get it well aired. One of the best mild manures for nurseries is obtained from turf-ash, which is prepared by making dome-shaped kilns of alternate layers of firewood and of sods, the latter being placed two or three thick with the grass turned inward. The soil may also have to be corrected by addition of sand, loamy clay, lime, etc.

Permanent nurseries should be provided with the proper buildings for storing tools, seeds, stables for any cattle which may be kept, office, etc. For the housing of the establishment it should be borne in mind that it is false economy, in countries where tropical diseases are prevalent, to think that any kind of shed is good enough for native workmen. Good houses mean healthy and contented workmen, and secure continuity of work. Especially in places where mosquitoes are prevalent, the doors and windows should be provided with mosquito-proof wire-netting; in damp localities the houses should be well raised from the ground, either on plinths or on piles, and strict attention should be given to sanitation, both in the provision of proper latrines and in insisting that no puddles be left on the ground where mosquitoes may breed. The same remark applies to empty tins and pieces of glass or earthenware, within

which rain-water collects and mosquitoes breed. In temporary nurseries it is not possible to erect buildings on the same scale as in permanent nurseries, but the same general rules may be applied, and wire-netting for the doors of the huts should be provided.

In unhealthy localities it is wise, if possible, to secure the services of the local inhabitants, who are more inured to the climate than those from outside.

CHAPTER V

[PRELIM]INARY OPERATIONS ON AREA TO BE AFFORESTED

[BEFOR]E starting the afforestation of an area it is usually [necessa]ry to carry out some preliminary operations, [the na]ture of which will vary according to the locality [and t]o the method of afforestation which is to be [adopte]d. These operations are usually confined to one [or mor]e of the following:—

Fencing,
Clearing,
Draining,
Irrigation,
Lining, and
Tilth of the soil.

[As] regards *fencing*, the subject has already been [dealt] with in the chapter on Nurseries. The areas [which] are taken up for afforestation are, however, [usually] of much greater extent than nurseries, and the [cost] of fencing may, in consequence, amount to [conside]rable sums. It is therefore necessary to select [the ch]eapest effective material. This will of course [depend] on the kind of animals which are likely to do [damag]e to the young plants. If these are absent the [fence m]ay be dispensed with; otherwise, taken all in [all, bar]bed wire fences are the cheapest and best except [for sma]ll rodents and ruminants, which can be kept out [by w]ire-netting. Sometimes trapping and shooting [su]ffice, but animals soon become wary and avoid

both trap and hunter; or, if the animals show a predilection for certain kinds of plants, these may be smeared or sprayed with a substance which renders them unpalatable. This has to be repeated at frequent intervals, otherwise the young shoots which have sprung since the last spraying will soon be nibbled off. In some places live fences made of aloes or cacti are popular, but it must be remembered that the strength of a fence is that of its weakest spot, and that the individual plants constituting a hedge do not all grow with the same vigour. A gap is soon made at the spot where the plants are weakest, and this, once made, is difficult to close again. The plantations made along the Ganges Canal were fenced with aloes; there was succulent grass under the trees when the outside country was parched up, and herds of cattle, probably assisted by herdsmen, soon managed to find various points of ingress.

In all cases where the plantations are left unfenced they should be clearly demarcated, and, where there is any danger from fire, fire-lines should be cleared round them and kept clean. The width of the fire-lines will vary very much according to locality; in dry places with abundant brushwood and grass, which will readily burn and fragments of which are blown to a considerable distance, it will be necessary to burn away from the cut fire-line to a safe distance.

Clearing means the partial or complete removal of brushwood and herbaceous plants growing on the area to be afforested.

In certain places, as *e.g.* in Ceylon plantations, it is usual to clear the whole ground before it is planted, whether with tea, coffee, or with forest trees; but this is a system which has many drawbacks as well as advantages, and which is by no means universal elsewhere, the clearing being more usually limited to the weeding of strips or patches, or even occasionally dispensed with.

In flat countries, or in such as have only a very

gentle fall, there can be no harm in complete clearing; on the contrary, it is beneficial, and it is only on the grounds of expense that partial clearing is resorted to. On hill slopes, however, where the rush of water is to be feared, complete clearing easily leads to erosion and to the surface soil being carried away during downpours of rain. It is for this reason that, in Ceylon, the hill-sides are seamed with drains to check the impetus of this surface drainage. This is not only an additional expense, but it fails to arrest entirely the disappearance of the surface soil, notwithstanding the fact that the soil is a fairly tenacious clay. In such places the scour would be greatly reduced by terracing the slopes, as is done in the East for rice-fields, but it would be an additional and heavy item of expenditure, and would not be usually justifiable for forest plantations on this score alone.

My own experience is that complete clearing is necessary only in places where the soil is taken up by a dense mass of plants having a network of rhizomes which would seriously compete with the young plants for the possession of the soil. It also appears that trees which are surface feeders require a greater area of cleared ground round them than those which have a deep root-system.

When partial clearing is done in strips, these, when made on a slope, should be made horizontally. The width of the cleared strips will greatly depend on the nature of the growth left standing on the uncleared strips, on whether the area is to be sown or planted, and, if planted, on the size of the transplants and whether they are surface feeders or not. The width is rarely less than 60 cm. (2 ft.). It is more usual to clear in patches which are made either rectangular or circular, and the size of the patches will be directed by the same considerations as those which affect the width of the cleared strips. Patches cleared on a hill-side should be arranged somewhat like a chess-board, but not touching one another, so that in whatever

direction water may flow it may be checked by the vegetation surrounding them.

In the Tropics, where weeds spring up luxuriantly whenever there is sufficient moisture and where the surface hardens easily in the dry weather, it is not generally advisable to do away entirely with clearing.

Wherever clearing has to be done, whether complete or partial, it should be done thoroughly. Rhizomes and roots which would compete with the young plant for possession of the soil should be carefully taken out, and all weeds, etc., should be burnt in heaps after being dried in the sun. This burning should be carried out in such a way that it will not be liable to spread to adjoining lands or to trees which are already standing on the area.

Under *draining* may be included two very different operations, the one having for object to remove excess moisture in the soil, while the other is intended to check the rush of surface water coming down slopes during tropical rainfall.

In dealing with *water-logged soils* it is necessary to ascertain the cause of their insufficient drainage. There may be, on the surface, a layer of partly decomposed humus, which would have to be partly removed and the remainder worked up and exposed to the air; or the top soil may overlie a pan of impermeable soil, such as clay, and sufficient drainage may be obtained, if this impermeable layer is not too thick, by breaking or blasting through it at a sufficient number of places. Swampiness may also be due to the sluggish current of the stream which should drain it; this may be remedied either by blasting or otherwise removing any boulders which may obstruct the current, or by widening the bed, or again, where the course of the stream is very serpentine, by cutting across loops and thus securing the same fall in a much shorter distance. More usually the excess moisture is removed by means of drains, the depth of which will vary according to that to which the soil is to be drained, and will be

very slightly greater than that point. The drains may be made either open or covered. For large works covered drains may be used, as they are not apt to get choked or silted up in the same degree as open drains, into which no end of silt and refuse collects, and which must be more constantly looked after. But the cost of making them is much greater than that of open drains, and for ordinary forest works the latter will usually suffice.

The drains are usually cut with sloping sides, the gradient of the slope varying according to the nature of the soil. In sandy soils the slope may be 1 in 3, and it may be increased according to the hardness and tenacious nature of the soil until the sides are almost perpendicular. On tea estates in Ceylon the sides are made perpendicular, but the soil is very tenacious, and even there it would be preferable to slope them a little.

In a small area it may be sufficient to have only one size of collecting drains, but where operations cover more ground there may be two or even three classes of drains. These may be divided as follows:—[1]

The *collecting* drains, which take up the water directly from the layer of soil to be drained; the *secondary* or *receiving* drains, which carry away the waters passed into them by the collecting drains; and the *main* or *outflow* drains, which are only required when more than one small basin is being drained. The secondary drains then discharge themselves into one channel which carries their accumulated volume of water away. In the plan shown in Fig. 48 the collecting drains are indicated at *a*, while the secondary drains are denoted by *b*, and the main drains by *c*. This discharges all the water collected in the basin into a river which carries it away.

The main and secondary drains are intended to carry away the water as quickly as possible, and should be made at right angles to the contour lines, *i.e.* straight down the slope, unless the soil is too friable or the slope

[1] Fernandez, *Indian Sylviculture*, p. 229.

too great to permit this. In the loosest soils the slope should not be greater than 1 in 13, but it may be increased on tougher and more rocky ground. It may also be possible to carry these drains down a steep slope by terracing the fall, *i.e.* by cutting it into steps which will

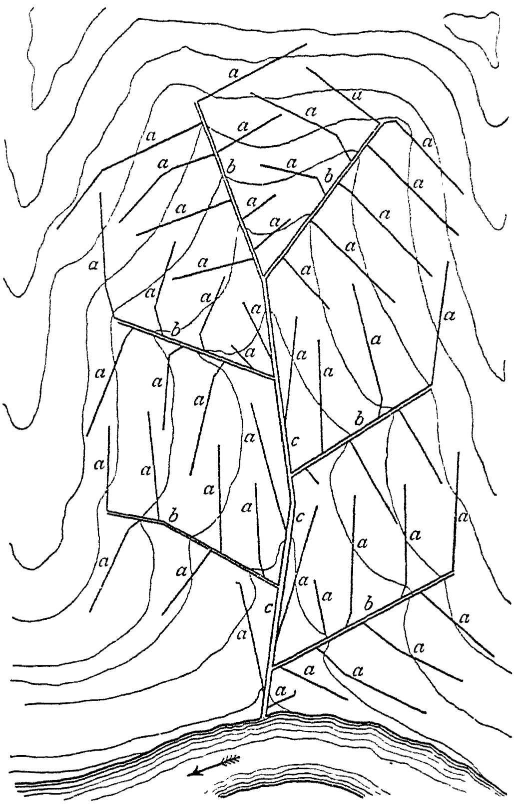


FIG. 48.

check the rush of the water. In this case it may become necessary to put in masonry aprons to prevent scour.

The collecting drains should be constructed in such a way as to collect as much water as possible while allowing the water so collected to flow off without check. They should therefore have a gentle slope, *i.e.* obliquely to the general slope of the ground.

When cutting drains it is useful to remember not to allow two drains debouching from two sides into a larger drain to have their opening opposite to one another, as the opposite currents of water on meeting may be checked and proper drainage may not be effected. This is particularly the case when there is much water coming from the drains, and especially so when the fall of the drain is slight. As an example of this I may quote the Blue Nile, which joins the White Nile between Khartoum and Omdurman. When the former comes down in flood it holds up the waters of the latter to such an extent that its effects are felt up the White Nile for two or three hundred miles.

In making drains on swampy soil it may become desirable to consider the effect of this drainage on

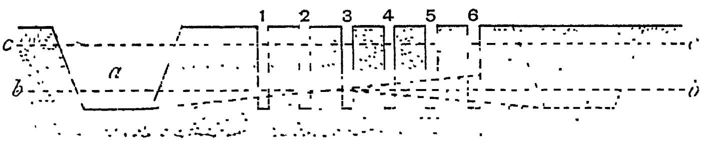


FIG. 49.

forest vegetation growing on land above this area and outside of the drainage scheme. The drainage may have the effect of depriving the trees of the moisture which they have become used to receiving, and of injuring them.[1]

The depth to which the soil will have to be drained will depend on the species which will be put in; as a rule it will not be much more or much less than 1 metre (3 ft.).

As regards the distance to be left between the collecting drains, the following method may be adopted for gauging it:—[2]

The soil having to be drained to a depth indicated by the line *bb* in Fig. 49, an experimental drain *a* is cut, and, in a line at right angles to its course, a number of

[1] Schlich, *Man. of Forestry*, vol. ii. [2] Heyer, *Waldbau*, p. 77.

holes, 1, 2, 3, 4, etc., are dug to the same depth as the drain. The lower extremity of the drain is then blocked, and water is allowed to collect within it. When the drain is nearly full, say up to the line *cc*, it will be found that the holes, 1, 2, 3, 4, etc., are full to the same level. The drain is then opened and allowed to empty itself, and after a short time the level of the water in the holes will be examined. It will be found that the nearer to the drain the less water will remain in the holes. One of these will be empty down to the level *bb*. This hole (No. 3 in the figure) will determine the distance between the drains, for it will be half-way between the drain made at *a* and the next. The trace for the drains should be laid out with the spirit-level, unless the area is very small, in which case it can be laid out with the eye.

The drains which are cut on *hill-sides* to prevent erosion are laid out on a similar principle to those which are made to drain a water-logged soil. The main and receiving drains are cut along lines of steepest descent, while the collecting drains are laid obliquely to the slope. These are usually given a steeper gradient than is given to those in swampy soil, especially in places where there are torrential falls of rain, as it is necessary to have the water led off quickly, otherwise the drains will soon overflow. In Ceylon, where these drains are much used on tea and other estates, they are often given a fall of 1 in 15, their width being 18 inches (45 cm.) and their depth 12 inches (30 cm.). In softer soil, however, their width at the top should be greater. These drains can be laid out with a level or with some kind of clinometer or "road tracer."

As regards the distance between the drains, no hard-and-fast rule can be made. It will depend on the amount of clearing made, on the slope, on the composition of the soil, and on whether the rain comes in moderate, evenly distributed showers, or in sudden, violent downpours.

The drains are cut during the dry weather, usually

;he clearing has been completed. In many ways ıld be better to cut them before the clearing has ɔegun, as they would check the rush of water from howers from the outset; but, on the other hand, would soon get choked by débris washed into them, much labour would have to be expended in ng them out. As it is, a certain amount of this be done after the first heavy fall of rain. It is ;ary to see that the drains are kept free and on properly until the young plants have formed ınopy, when, owing to the shelter given to the d by the crowns and by dead leaves and other us, the rush of water will be reduced and the ; trees will be strong enough to withstand the ıre of flowing surface water.

ll draining operations are expensive, and before taking them it is advisable to consider carefully ɔssibility of avoiding them. Small swampy places ɔften be left unafforested, or it may be possible to ı species which can live in such soil, and, on steep especially, total clearing of the soil may be ed and clearing in patches substituted.

ı an arid locality, and particularly on a soil which ıot retain moisture, it may be necessary to employ *ıtion* to start the young plants, and even, in some this irrigation has to be continued throughout fe of the trees. This is of course very expensive, ;an only be justified under special circumstances. Changa Manga plantation, which was started to y fuel to the town of Lahore in India, and which has raised on a very porous soil, is an example of this. ɔr small areas, the methods of irrigation described e chapter on Nurseries will suffice, but for larger larger works are necessary, a full description of ı does not belong to a volume of the nature of but to special treatises on irrigation.

he system of distribution is generally the reverse at adopted for drains. The main canals take up vater from a river, lake, or tank. From these

branch out various secondary canals which lead the waters to different sections of the ground, while the distributing channels take the water to the particular plot of ground which they are destined to irrigate.

The above system is that used for *perennial* irrigation, *i.e.* for that which has to be carried on practically throughout the year. It may also be used for shorter periods, and if required only when the source of supply is at the flood, the main canals are made more shallow, being so constructed that the water flows into them only when the river, lake, etc., has reached a certain level. This method of irrigation, called *flood*-irrigation, may become necessary when the demand on the water-supply is greater than can be supplied to all applicants all the year round. In this case the most common method of supplying water is by *basin*-irrigation. The area, having been carefully surveyed and levels taken, is divided into a series of basins which are bounded by dykes made sufficiently strong to hold up a certain depth of water. These basins are flooded each in turn, the water being allowed to stand and gradually to soak into the soil, after which the crops are sown or planted.

On land with a very gentle gradient basin-irrigation may be obtained from rainfall by constructing small dams across the lower side of the ground and along the sides to retain the surface drainage, which is allowed to soak in, after which the crops are put in. For afforestation works basin-irrigation would probably be more suitable to sowing than to planting, excepting on sandy soils.

Where irrigation is obtainable it is useful for the reclamation of salt soils. The frequent washing out of the soil may make it sufficiently sweet to be able to grow the trees required. This process of sweetening may be assisted by growing crops which can thrive in a soil which contains some salt, such as *e.g.* the common *Sorghum* or Dura, the "Fox-tail" sedge (*Juncellus alopecuroides*), etc.

The next operation to be described is that of *lining.* ь means marking the places where plants or seeds are) be put in. For broadcast sowing it is of course not equired, and it is also sometimes omitted for dibbling ı seed, especially on hill-sides; but where it is desired › have a uniform plantation it is done, as it makes ıpervision easier and also makes it possible to estimate əforehand how much seed or how many plants will be equired. Failures can also be more easily noticed and placed. When the clearing is done in lines or in ıtches the lining precedes it, as it also indicates the aces which have to be cleared in the middle of which ιe plants will have to grow.

The places where the seeds or plants will be put in

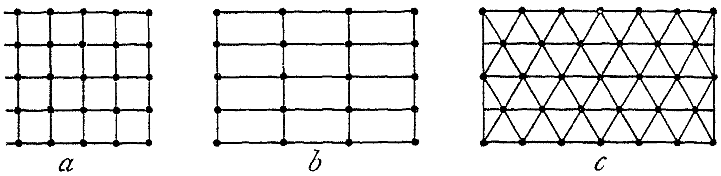


FIG. 50.

e marked by means of pegs, which are stuck into the rth at regular intervals. There are three chief ethods of lining, viz. by *squares*, by *rectangles*, and ' *equilateral triangles.*

In the "square" method the pegs are put in in equi-stant lines, the distances of the pegs on the lines ing the same as the distances between the lines. ith the "rectangular" method the pegs are again .t in in equidistant lines, and they are also equidistant the lines; but the distances between the lines are not e same as those between the pegs in the lines—they ͅ either greater or smaller, as the case may be. When ə pattern is that of equilateral triangles the distance tween the lines will be that of the height of the angle, while in the lines the pegs will be spaced at a stance equal to its sides. In Fig. 50, *a*, *b*, and *c* show spectively the square, rectangular, and equilateral

triangle patterns of lining. There is also the "quincunx" pattern, which is merely a modification of the "square" method, a fifth peg being put in in the centre of each square.

Of the three methods the "square" is probably the most commonly used, as it is the most easy to lay out. The "triangular" pattern has the advantage of allowing the area to be more fully stocked, and as each tree is surrounded by six others at equidistances the crowns grow more uniform in shape, and consequently the boles of the trees are more cylindrical and the timber produced of more even growth; but this system requires a greater outlay on seeds or on young plants, the cost of upkeep and supervision is greater, and the laying out is more difficult. In the "rectangular" system the crowns of the trees grow broader in one direction than in the other, and the growth of the rings of wood is thus liable to be uneven and the timber obtained more variable in strength and more given to warping. On the other hand supervision is easier, and the method may be useful in areas which are already partly under timber and also for plantations of trees, the chief produce of which is not timber, as *e.g.* in Rubber plantations.

As the difference between the three systems becomes modified after the early thinnings, their respective effect on the leaf-canopy also disappears, and for this reason several foresters prefer the rectangular system as being the cheapest to carry out and easiest to supervise.[1]

The laying out of the area according to the different patterns may be done in different manners. The lines may be laid out from a base line by means of surveying instruments, such as the theodolite or prismatic compass, or with the cross-staff, the distances between the pegs in the lines being marked by means of a rope on which, at the required distances, are knots of coloured thread which indicate where the planting-pegs are to be put in. In the case where the triangular pattern is used

[1] Schlich, *op. cit.* vol. ii.

the distance between the lines will be equal to the height of the triangles. In each alternate line the first planting-peg will be put at a distance from the base line equal to half the distance between the plants (see *c* in Fig. 50).

Where labour is cheap and abundant, surveying implements are only utilised for laying two base lines at right angles to each other, or, if the area is large, for laying offsets from the principal base line from distance to distance, as guides to the workmen.

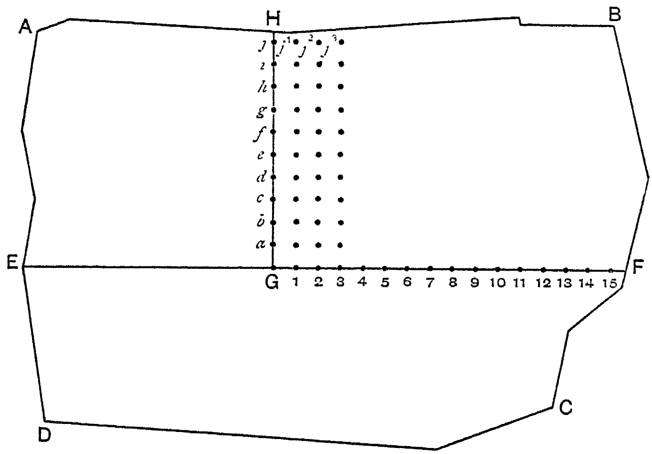


FIG. 51.

The following method of lining is used on Ceylon plantations :—

A piece of land ABCD (Fig. 51) having to be lined, a suitable base line EF is selected and marked out, and from the most convenient spot on it an offset GH is marked off at right angles to it. A rope, having knots of red cloth at distances equal to those which the lining-pegs are to have from one another, is then stretched from G towards F, and pegs put in by the red knots at points 1, 2, 3, 4, 5, etc. If the square pattern is adopted (as in the figure), the same rope is stretched towards H and pegs put in at *a*, *b*, *c*, *d*, etc.

If the rectangular system is selected the rope stretched from G to F would have knots of one colour, say red, showing the distances between the pegs in the lines, while the rope from G to H would have knots of another colour, say yellow, to show the distances between the lines, or *vice versa*. Two men are required as guides on the wings of the work, one standing at G, while the other stands at the other end of the offset, or as far away as is convenient for the work (at j in the figure). The latter holds a bundle of lining-pegs, and a staff of the same length as the distance which the pegs must have between them on the line. Between the two men stand a number of boys, each with a bundle of pegs. If they are inexperienced, or if the distances between the lines are great, one boy will be required at each line (viz. at a, b, c, d, etc.); but if the distances between the lines are not great, one boy will be sufficient for several lines after he has had some practice. When all are in position along the line GH, the man at G steps to peg No. 1 along the base line GF, while the man at j measures off the distance jj^1 at right angles to GH with his staff, puts in his peg, and stands at j^1. The two men now guide the boys and keep them in a line and at proper distances from each other. When this is done the boys put in their pegs, and the two men step to pegs No. 2 on line GF and to j^2 in the same line as j and j^1, and so on. After some practice the men and boys become very expert at this work. When the portion of the land comprised within GHB and F has been completed, that on the other side of the offset, viz. GHA and E, can be done from the same offset, after which the portion on the other side of the base line EF can be tackled.

The triangular pattern is not used in Ceylon, but a similar somewhat more lengthy system would have to be adopted. The distances of the pegs at 1, 2, 3, 4, etc., on line GF, would be equal to the sides of the triangles, while those on the offset, at a, b, c, d, etc., would be equal to the height of the triangles.

The lining of each plot would have to be done in two journeys, or by two separate gangs of men and boys, the first putting in the pegs along the lines starting from *b*, *d*, *f*, *h*, and *j*, while the second would complete the lining along lines *a*, *c*, *e*, *g*, and *i*. In this second operation one man would stand at *a* and the other at *i*, and the first distance a^1 measured and pegged out by them would only be equal to half the length of the side of a triangle; but all the next distances (a^2, a^3, etc.) would be equal to the full length of the side of a triangle (Fig. 52). There are other methods of carrying

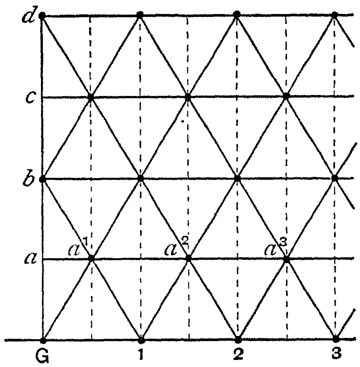


FIG. 52.

on the operation of lining, but as this method has yielded very good results with Indian and Sinhalese coolies, it will answer well with most classes of workmen.

The distances between the lines and between the plants on the lines will greatly depend on the species to be raised; on the object which they are destined to fulfil, whether for timber, firewood, or for other produce; on the configuration of the ground; on atmospheric conditions, and on the soil. No hard and fast rule can be laid down, but it may be said that, as a rule, slow-growing species will be put in closer together than those that are quick-growing, in order to form leaf-canopy as early as possible; also, that if a nurse-crop which will be removed early is raised at the same time as that

which is ultimately to cover the ground, the spaces should be smaller. In places where winds or floods and landslips are to be feared, and especially in wind-belts, the plants should come up sufficiently dense to offer a strong resistance. A poor soil will not be able to raise a very dense growth, but as the soil improves under cover it is better to err on the side of denseness. Spacing will also depend on whether seeds or transplants are put in. As the prospect of success is much smaller with seeds than with plants, the lining should be much closer for the former; and the stronger and more vigorous the transplants are the greater the spacing that can be given to them.

As it is necessary to know how many lining-pegs will be required, and, later, how much seed or how many plants will have to be provided according to the pattern and distance between the plants selected, certain formulae are employed for calculating these numbers, which give very fairly satisfactory results. It is, however, always good to have some reserve either of seed or of plants over and above the number calculated to provide for rejections in the field, for it will always happen that a certain proportion of the seed will turn out bad or that some of the seedlings will be misshapen or injured in lifting or in transport to the field.

Let N be the number of planting or sowing spots, L the length of the piece of land to be afforested, and W its width, let d represent the number of planting or sowing spots in a line, and D the distance between the lines.

In the square pattern the distance between the lines is the same as that between the spots in the lines, *i.e.* $d = \mathrm{D}$ and

$$\mathrm{N} = \left(\frac{\mathrm{L}}{d}+1\right)\left(\frac{\mathrm{W}}{\mathrm{D}}+1\right) = \left(\frac{\mathrm{L}}{d}+1\right)\left(\frac{\mathrm{W}}{d}+1\right) = \frac{\mathrm{LW}}{d^2}+\frac{\mathrm{L}+\mathrm{W}}{d}+1.$$

In the "rectangular" pattern d is not $= \mathrm{D}$, and the formula is, therefore :—

$$\mathrm{N} = \left(\frac{\mathrm{L}}{d}+1\right)\left(\frac{\mathrm{W}}{\mathrm{D}}+1\right) = \frac{\mathrm{LW}}{d\mathrm{D}}+\frac{\mathrm{L}}{d}+\frac{\mathrm{W}}{\mathrm{D}}+1.$$

In the "equilateral triangle" pattern, the distance d between the spots in the lines will be equal to the sides of the triangles, while the distance D between the lines will be equal to the height of these triangles, that is, it will be equal to $d \sin 60^\circ = 0{\cdot}866d$ or, say, $0{\cdot}87d$. Here, as in every other line, the first spot is at half the length of the side of a triangle farther along its line than the preceding; the calculation may vary according to whether the number of spots in each line is equal or whether there is one less in each alternate line, but for all purposes the following formula will suffice :—

$$N = \frac{LW}{0{\cdot}87d^2} + \frac{1}{2}\,\frac{L+W}{d}.$$

The annexed two tables give the number of planting spots calculated, according to the metric system, for one hectare, and by the English measurement for one acre :—[1]

[1] The second table is copied from the *Manual of Indian Sylviculture*, by E. E. Fernandez, p. 299.

METRIC MEASUREMENT

Planting Distance in the Lines in Metres.	Number of Sowing or Planting Spots in a Hectare on the									
	Square Pattern:	Equilateral Triangle Pattern:	Rectangular Pattern: the Distance, in Metres, from Line to Line, being							
			0·75	1	1·25	1·5	1·75	2	2·5	3
0·5	40,100	46,180	27,000	20,300	16,280	13,600	11,690	10,250	8,240	6,900
0·75	18,040	22,820	...	13,570	10,850	9,090	7,810	6,850	5,510	4,610
1	10,200	11,720	...	...	8,180	6,830	5,870	5,150	4,140	3,470
1·25	6,560	7,360	...	...	...	5,480	4,710	4,130	3,320	2,780
1·5	4,580	5,160	...	...	...	...	3,930	3,450	2,770	2,320
1·75	3,380	3,810	...	...	...	...	...	3,000	2,380	2,000
2	2,600	2,920	...	...	...	...	...	...	2,090	1,750
2·5	1,680	1,880	...	...	...	...	...	...	...	1,410
3	1,180	1,310								

BRITISH MEASUREMENT

Planting Distance in the Lines in Feet.	Number of Sowing or Planting Spots in an Acre on the										
	Square Pattern:	Equilateral Triangle Pattern:	Rectangular Pattern: the Distance, in Feet, from Line to Line, being								
			3	3½	4	5	6	7	8	9	10
1	...	...	14,940	12,870	11,310	9,140	7,680	...	...	...	...
1½	...	...	9,960	8,580	7,540	6,090	5,120	4,430	3,910	...	...
2	11,100	12,800	7,470	6,430	5,660	4,570	3,840	3,320	2,930	2,630	...
2½	7,140	8,180	5,980	5,150	4,520	3,650	3,070	2,660	2,340	2,100	1,910
3	4,980	5,700	...	4,290	3,770	3,040	2,560	2,210	1,960	1,750	1,590
3½	3,680	4,210	...	...	3,230	2,610	2,190	1,900	1,680	1,500	1,370
4	2,830	3,230	...	...	...	2,290	1,920	1,660	1,470	1,320	1,190
5	1,830	2,090	...	...	...	...	1,540	1,330	1,170	1,050	960
6	1,280	1,460	...	...	...	...	...	1,110	980	940	800
7	950	1,080	...	...	...	...	...	...	840	750	680
8	730	840	...	...	...	...	...	...	...	660	600
9	580	670	...	...	...	...	...	...	...	...	530
10	480	540									
12	340	380	1,350	1,160	1,010	810	680	580	510	450	410
15	220	250	...	950	830	670	550	480	410	370	330

The above tables have been calculated for one hectare or one acre only. When large areas have to be afforested the following rough methods of calculation can be employed as approximately correct:—[1]

[1] Schlich, *op. cit.* vol. ii. p. 182.

Square pattern—

$$N = \frac{43560}{\text{Square of planting distance}}.$$

Rectangular pattern—

$$N = \frac{43560}{\text{Distance between the lines} \times \text{distance in lines}}.$$

Triangular pattern—

$$N = \frac{43560}{\text{Square of side of triangle}} \times 1{\cdot}155.$$

The next operation to be described is the *tilth* or *preparation of the ground for the actual reception of seeds or plants.* It is an operation which is sometimes neglected in the case of broadcast sowing or of dibbling in seed or even sometimes with small transplants ; but in places where weeds spring fast and dense, the future of the young plantation is much more likely to be assured by this preliminary work.

In places where broadcast sowing or dibbling in of seeds is to be done, and where the clearing has been done with a plough, the area should be gone over with a chain-harrow as preparation for the seed, and the same preparation may be given for small transplants; but where the clearing has been done in patches the soil has to be worked up by hand, and the amount of work will depend on the nature and size of seed or transplant and on the soil. For reception of the seed it may be sufficient to give a few strokes of the hoe at the spots marked with lining-pegs; or if the ground is hard, a pick-axe may have to be used, or special instruments such as soil-augers (Figs. 53 and 54); or when the soil is tough as well as hard, a heavier implement, such as the tramp-pick (Fig. 55) or a crow-bar. If there are still rhizomes or roots in the soil, the torsion-rake (Fig. 56) can be employed for breaking them up and loosening the soil.

For transplants of an average or large size holes will have to be dug out. This has to be done even

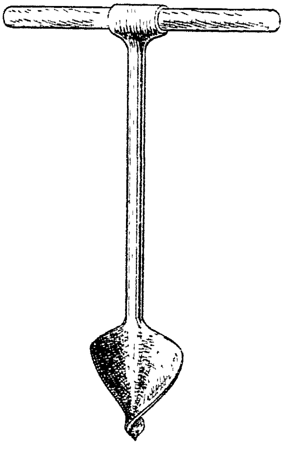


FIG. 53.

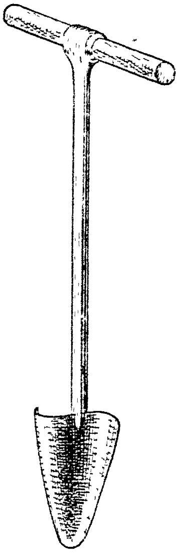


FIG. 54.

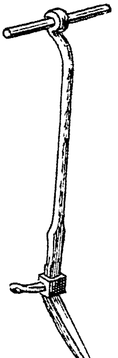


FIG. 55.

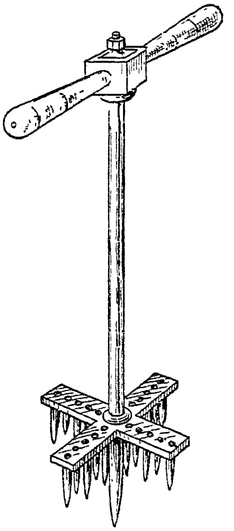


FIG. 56.

when these have to be planted above the ground-level, on mounds, in places which are considered too moist for planting at ground-level. In planting districts, the usual size of the holes for average-sized seedlings is 18 in. × 18 in. × 18 in. (45 cm. × 45 cm. × 45 cm.); but it will depend on the size of the transplants and also whether, as in arid localities, they have to be planted at a level lower than that of the surrounding ground. When digging the holes the soil should be taken out, and after stones and roots have been rejected it should be heaped up alongside the mouth of the hole to be well aired before the plants are put in.

In overmoist soil it may be necessary to do some *ridging* by digging out trenches and heaping up the spoil earth between them. On these ridges seed is sown or plants are put in. For arid soils trenches can also be prepared. It is usual to leave a margin between the mouth of the trench and the spoil earth in places where heavy downpours are likely to occur, which might drown any seedlings growing at the bottom. Seed is then put in at the bottom of the trench, and more seed on the margin on the brim to provide for all emergencies.

CHAPTER VI

SOWING AND PLANTING

(*a*) Sowing

Direct sowing can be done *broadcast*, or *in strips*, or *in patches*, or by *dibbling in* without or with tilth.

Broadcast sowing may be carried out on soil which has been given no preparation, or on soil which has been previously cleared and tilled. The seed is usually scattered by hand by people carrying bags of seed. After this is done, in the case of untilled land, the seed is left to take its chance, or is raked over and pressed in, but on tilled land a light harrow is passed over, and it may be advantageously rolled afterwards.

In sowing, care should be taken to scatter the seed as uniformly as possible; and if the seed is small or light, a calm day should be selected for the operation. If a mixture of species is desired, the seeds of the different species to be raised should be mixed together in the required proportions before the sowing is done, and if certain species require special treatment of the seed this should also be done before sowing. The number of seeds sown should be largely in excess of the number of seedlings which it is desired to raise; in other words, seed should be scattered thickly, because there is every chance that only a small proportion will develop into seedlings. This is especially the case when the sowing is done without previous tilth of the soil.

The seed is sown just before the beginning of the

rainy season, or if it has been specially prepared so as to hasten germination, just after the rains have begun. On tilled land, however, it should not be put in while the ground is still over-saturated with moisture, as it will make the harrowing and rolling impossible.

Although this system of sowing is cheaper, it usually gives very uneven results. Even where conditions are otherwise favourable the seedlings are apt to come up very irregularly, some places being almost overcrowded with seedlings while others have few or none at all. Broadcast sowing without previous preparation of the ground is only suitable to very few localities in the Tropics, such as have a sufficiently moist ground during the process of germination and only a scanty crop of weeds. Such are, *e.g.*, the low, muddy banks of a river from which the water recedes during the dry season, but which retain enough moisture during a sufficiently long time to permit the seedlings to establish themselves. Generally speaking, broadcast sowing is most likely to succeed in areas which have been under cultivation for some time, and are therefore comparatively free of weeds. It may also be possible to sow tree-seeds broadcast, together with seed for an agricultural crop; and if this is repeated for two or three years a sufficiency of seedlings may be obtained after this process, provided that ploughs be not used after the first sowing.

When sowing *in strips* the seed is not scattered over the whole area, but along lines which are marked out on the ground. Along these lines the seed is put in either continuously or dibbled in at regular intervals in furrows or trenches or along ridges, or there may be a combination of trench and furrow or of trench and ridge, or even of all three. The lines may be single between uncultivated strips, or, especially if there are many invading weeds in the uncultivated strips, there may be several lines in each cultivated strip.

When sowing in furrows, it is intended that the seed should lie only deep enough below the surface to be covered with a layer of earth up to ground-level.

The furrow is then prepared either with a light donkey-plough or with a hoe, or else with a trowel-hoe (Fig. 28), or with the share-hoe (Fig. 57), according to the depth to which the soil is to be worked up. In heavy or stony soils the pick-axe or tramp-pick (Fig. 55) will have to be used. In hilly ground these furrows should be made horizontally, otherwise they will be liable to be turned into watercourses. The furrow being made, the seed is dropped in either by hand or with the help of a sowing-horn, which can be easily prepared with a bottle by attaching to its mouth a conical piece of

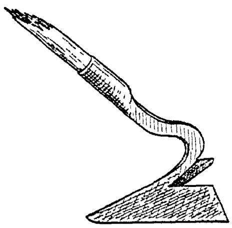


FIG. 57.

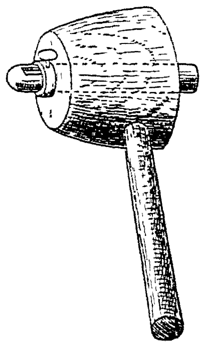


FIG. 58.

leather with an aperture at the pointed end of the requisite size to let the seed out just sufficiently fast to give out a continuous supply. Special seed-horns are also sold, which have at the extremity a screw by which the size of the aperture can be regulated. The seed can also be dibbled in from distance to distance, the holes being made with the finger or with a planting stake (Fig. 42), or with a dibbling hammer, which can be regulated so as not to penetrate into the earth deeper than is required to give the proper depth to the seeds (Fig. 58). After the sowing has been done in a furrow, earth is raked in over it.

As has already been stated, seed may be sown in trenches when the rainfall is scanty in order to give

seedlings a better chance of obtaining the requisite moisture at a lower level. The sides of the trench also afford a certain amount of shade to young seedlings when made in the proper direction. On flat land, therefore, it will be preferable to give to the trenches a direction which will give most shade during the hot, dry weather, and which will vary slightly according to the latitude north or south of the equator. On hilly ground they should be made horizontal; and, both on hilly and flat ground, should be interrupted at short intervals, not only to collect water, but to prevent the trenches being turned into drains. The seed can be sown at the bottom of the trench either in furrows or dibbled in from distance to distance. When there is an uncertainty as to whether the dry season may not be interrupted by some heavy downpours which might fill the trenches and kill the germinating seed or the seedlings, seed is sown, not only at the bottom of the trench but also along its lip. If the season turns out dry, the seeds at the bottom of the trench will have the best chance of success; but if rain fills the trenches, those on the brims will obtain the necessary moisture from them.

On water-logged soils the seed can be sown on ridges, and the young seedlings can be thus given a fair start.

When sowing *in patches* these patches are usually arranged in squares, rectangles, or equilateral triangles as described in the preceding chapter, except perhaps on rocky ground, or on soil of varying quality where they may be made where the plants are most likely to succeed. The patches may be made of varying size, from 30 to 90 cm. square (1 to 3 ft. square), or they may be rectangular, like interrupted strips, in which case they are destined to contain a larger number of seed. The soil having been prepared the seed is dibbled in. It is usual to put two or three seeds at least in the same patch, but not in the same hole, in order to provide for any failures. If more than one seed germinates, the superfluous seedlings can afterwards be lifted out and

utilised in filling up "vacancies," *i.e.* patches in which none of the seed has come up. In dry localities the patches may be sunk somewhat below the level of the ground in the shape of small pits, and in moist localities small mounds can be gathered together with the help of the hoe and the seed dibbled into them.

Seed may also be sown by being dibbled in *without previous preparation of the ground.* In this case it is not usual to mark out beforehand the spots where it will be put in. The men who dibble in the seed are put in a line and given a direction, and keep approximately within regular distances of one another. The seed is then dibbled in each time the men take a step or two steps forward. This method, although it has the advantage of cheapness, does not yield as good results as those previously described, unless the soil is of good quality and yet free from invading weeds. It is more suitable to those species which have a deep rooting apparatus than those which have superficial roots. It is used mostly to fill in blanks in land already under forest, and also to assist natural regeneration. When the seeds are large, a hoe is used instead of a stake or dibbling hammer.

(*b*) Planting

There are two broad divisions in the methods of planting, viz. with earth attached to and enclosing the roots, and with the roots free of earth. These are commonly called, respectively, "planting with"—or without—"balls of earth," although the "ball" is by no means necessarily globular but more commonly cylindrical, conical, or pyramidal. There are certain general rules which apply to both methods. They are that both the root-axis and the stem should be vertical when the plant is put in, that the root-collum should be at the level of the ground when put in and when the earth has settled, *i.e.* that the plants should be put in neither too deep nor too shallow, and thirdly, that

there be complete contact between the roots and the surrounding soil.

(1) *Planting with Balls of Earth.*—The methods of lifting transplants from the nursery have already been described in Chapter IV. There is, however, this difference that whereas when lifting seedlings from nursery beds and putting them into nursery lines the transport is short and the transplants are out of the ground for a comparatively short time, the transport from the nursery to the plantation may be long, especially if the transplants come from a permanent central nursery. Particular care should therefore be taken, in lifting the transplants and during transport, to prevent the earth from breaking away. With small transplants having small balls of earth, these may be pressed together slightly with the hand if the soil is loose; but this should not be done to excess, especially if the soil is clayey, as this will prevent air from reaching the roots and will cause them to rot. I have known of considerable areas of plantation having failed owing to the balls of earth having been squeezed too hard. In the year following the planting nothing remained in the holes but hard balls of clay; the plants had died.

Large transplants should be taken out with particular care; cheap matting or sacking can then be tied round the balls of earth to prevent them from breaking.

When the transport is likely to be long and the plants to be exposed to the sun and heat, it will often be advisable to do a certain amount of pruning in order to reduce the transpiration. This pruning may be confined to the tender herbaceous shoots, or it may consist in removing a greater portion of the crown, and it may even be desirable to cut them back to a short distance above the root-collum, or, in planting parlance, to *stump* the transplants. Stumping is more often necessary for large than for small transplants. It should be done with a sharp pruning-knife, the cut being made upwards in a slanting direction. No

stumping can be done with species which do not coppice readily, as *e.g.* most Conifers, but a few of the side branches may be trimmed.

The cost of transport is a heavy item in the expenditure on plantations, and it should be done in the cheapest way possible. The cheapest and smoothest of all, where it is available, is transport by boat, but if this is not possible it may pay for large works to have portable tramways, or, where the nursery is above or below the plantation, to set up aerial ropeways. Failing these, carts should be used along the larger roads and handcarts along narrower ones, and even wheelbarrows may go along still narrower roads, but natives often seem to have an objection to using them. On steep paths the transport will ordinarily be by man, the transplants being carried in baskets or boxes, either by head loads or slung from a pole between two men; or, where the men are used to it, slung at either end of an elastic pole and carried by one man. This is the "bhangi" or "pingo" of the East.

In packing the transplants for transport they should be put in tightly to prevent the jar and motion shaking the balls to pieces, and good soil should be poured into the interstices to make the mass as homogeneous as possible. When packed into baskets these should be stiff, as the play on the baskets during transport will also be liable to break the balls of earth.

Before starting, a slight watering may be given with a watering-rose to keep the transplant fresh, and a light shading of ferns or light leafy twigs may be laid over them.

The plants having been transported to the field, they are taken out of their baskets or crates, and put into the planting holes which have been previously prepared. In Europe, in the case of plants lifted with the circular transplanter (Fig. 40), the holing may be confined to taking out a ball of earth at the planting spot with the transplanter, the hole being filled again with the ball of earth bearing the transplant. As the

hole is wider than the ball of earth by the thickness of the blade of the instrument, the ball of earth fits in easily. In the Tropics, where weeds are more abundant and spring up easily, there are not many places where a greater degree of tilth is not necessary.

If the transplants have been grown in supply-baskets, all that is required to be done is to break open the bottom of the basket in order to enable the roots to pass through into the sub-lying soil. The basket is held at the right level in the hole, while the spoil-earth, which has been lying airing near its mouth,

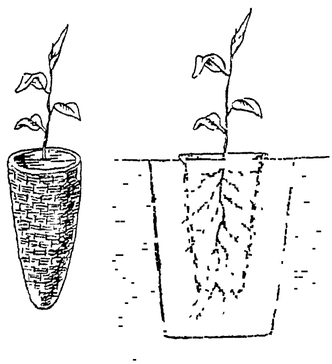


FIG. 59.

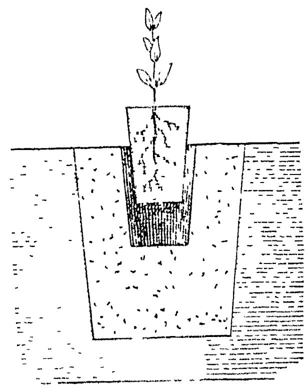


FIG. 60.

is raked in and pressed down so as to get complete contact (Fig. 59). The same method of planting is adopted with other plants having balls of earth round their roots. They should be examined, if the soil is clayey, before they are put in, to see whether the earth has been squeezed in too tight, and, if so, the surface of the ball should be slightly loosened. When the transplants are small, the holes can be partly filled with earth before they are put in; and when the plants have been lifted with the circular transplanter it will be, perhaps, best to fill the hole with earth, press it down, and then cut out in its centre a smaller hole with a circular transplanter of the same size. The ball is then

slipped in as into a sheath (Fig. 60) and pressed in to make thorough contact. This is a point which must be paid particular attention to, for nothing is worse for a plant than to be suspended over a void. The earth would gradually settle, the root-collum would become exposed, and the plant, no longer being properly supported, would ultimately lie prostrate.

With plants taken up with the Ceylon transplanter (Fig. 41), the metal cylinder should be removed before they are put in.

(2) *Planting without Balls of Earth.*—The plants having been lifted in the nursery with great care, they can be transported to the field by one or more of the various methods already described above. But, as the roots are not protected by balls of earth, special care must be devoted to keeping the transplants fresh. The baskets or crates in which they are packed should be lined with damp moss, if available; if not, with damp grass, ferns, or twigs. The plants may be laid in layers horizontally, and again covered with shading material which can be sprinkled with water. When the transport is fairly long, the plants may have their roots dipped in a mixture of fine clay and water before they are packed, or cow-dung may replace the clay. This will form a thin protective covering over them, and prevent them from drying up too rapidly.

With transplants without balls of earth, even more than with those which have them, it may be necessary to prune or stump them, and this is especially the case with large transplants. The roots, having to establish themselves in their new medium, would in many cases find it hard, at the same time, to supply the crowns with the necessary moisture and food.

The planting of small seedlings which have not yet developed any important lateral roots may be done by making a hole in the ground with a planting-stake (Fig. 42) if the ground has been previously prepared, or with a similar implement shod with iron called the "planting dagger" (Fig. 61), or "Buttlar's iron"

(Fig. 62) in somewhat tougher or untilled soils, or with a long crowbar (called "alavanga" by Ceylon planters), or the tramp-pick in hard stony soils. In most places in the Tropics it will be best to give some previous preparation to the ground.

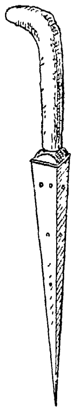


FIG. 61.

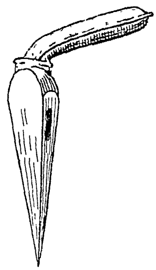


FIG. 62.

When the hole is made, the roots of the transplant are slipped into it, care being taken that the taproot goes straight down and does not get twisted in the process. It is important that this should be attended to, as plants with twisted roots do not develop properly. While the plant is being held in the hole, another hole in a direction slanting towards the bottom of the first hole is made with the stake, or whatever

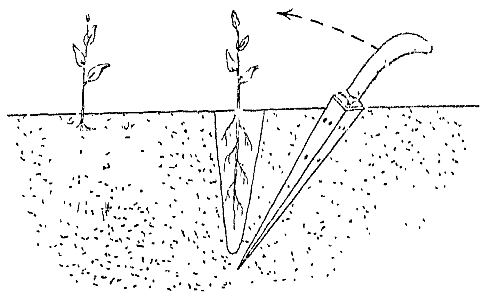


FIG. 63.

implement be used, and the latter is pressed towards the plant so as to close up the hole. The implement is then withdrawn from the second hole, which is closed by pressing down with the foot (Fig. 63), and so on.

Instead of a pointed instrument, the circular transplanter may also be used for making the hole. In this case the cylinder of earth which is lifted out is broken up and used for filling the space round the roots.

Another method of planting is by *notching*. This may be done with an ordinary flat spade, or with special notching spades (Figs. 64 and 65), or with a notching hatchet[1] (Fig. 66). Where the ground is not too hard the last-named implement will suit people accustomed to squatting best. The ordinary way of notching is to drive the spade or hatchet vertically into the ground and move it to and fro so as to make a wedge-shaped hole, into which the young plant is slipped, as is done for holes made with the planting dagger, and to close the hole by a slanting stroke of the spade, the handle of the spade being worked towards the plant. When the planting hatchet is used this method of closing the hole is not feasible, and some earth has to be broken up with the blade and dropped into the hole. This method can be used with plants which have lateral roots somewhat better developed than in the case of planting with peg or dagger.

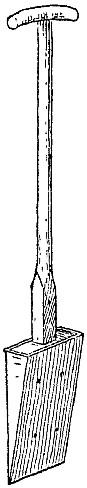


FIG. 64.

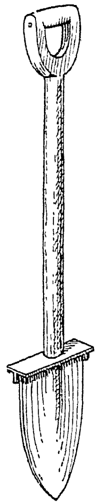


FIG. 65.

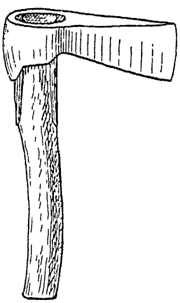


FIG. 66.

Another method of notching consists in making two vertical cuts with a spade in the soil in the shape of a T. The cross-cut is the last made, the handle of the spade being bent backwards so as to open out the two cuts at their junction. The plant is then slipped into this opening and drawn a little towards the extremity of the vertical cut of the T (Fig. 67). The disadvantage of this method is that in pulling the plant into the notch the roots cannot be

[1] Figs. 64 to 66 are adapted from Schlich's *Man. of Forestry*, vol. ii.

kept vertical, and that the young plant suffers from the outset from this defect. It is a method which can only be used where the soil is sufficiently cohesive to permit of the opening being made without crumbling in.

Transplants with a better developed root-system are usually planted in holes prepared as indicated in the last chapter. The width and depth of these holes will depend on the size of the transplants and on the soil of the area to be planted, and also on whether the plants are to be put in at a deeper or higher level than the surrounding soil.

The actual method of putting in the plants has already been described in the chapter on Nurseries;

FIG. 67.

but it is desirable to repeat the injunction of keeping the taproot vertical, of well shaking in the earth so that complete contact may be obtained and no cavity remains after putting in the earth, and of pressing the earth well home after it has been put in. The root-collum, at the end of the operation, should be level with the surrounding earth in the hole.

The holes are usually filled level with the surface of the soil of the field; but in dry localities it may be desirable to dig the pits deeper and to let the soil level in the hole be somewhat below the surface of the soil of the field. In wet localities, on the other hand, the level may be raised by making a mound over the hole in order to give the young plants a start in not too damp a medium. In places where there are torrential rains or a very strong sun it is not a bad thing to revet the sides of the mounds with protecting sods of

turf or with straw; twigs are dangerous, as likely to attract insects, and as increasing danger from fire.

In comparing planting of transplants with balls of earth to that of transplants with naked roots, it may be said that the former method offers much greater chance of success, as not only is the shock to the plant smaller, but a smaller number of root-hairs get torn in the lifting, and those which remain are already established in the soil and can continue their functions when they are put into the field. In lifting transplants with naked roots, the shock is greater, a larger number of rootlets are injured, not only in lifting but probably in transit and in replanting, and those which remain have to settle themselves in their new surroundings, which may include a soil of a totally different character from that of the nursery.

On the other hand, the item of cost of transport is enormously reduced when no balls of earth have to be carried, and this is such an important item that it may fix the method of planting. Where rainfall is fairly distributed after the time of planting, it will be generally possible to plant seedlings without balls of earth, and this method of planting is often used for filling blanks in a forest.

Whatever system of planting is adopted, it is desirable that the plantation be made a success from the very outset. A plantation with a large number of failures is more difficult to fill and to make a success than one which is properly dealt with from the beginning. The soil often deteriorates on the surface after being exposed, especially in the Tropics, where torrential rains wash the top layers of the exposed soil away. It is therefore desirable to get this soil sheltered by the crowns of the young plants as early as possible, and consequently, the sooner do these plants make a start, the earlier will this object be accomplished.

The distances to be left between the plants will depend not only on the size of transplants, their rate of growth, and on the soil and locality, but also on the

ect which the plantation is destined to fulfil. In all es it is desirable to protect the soil as soon as possible; l in the case of plantations which are being raised the production of timber one must aim at obtain- leaf-canopy without much delay. If, however, the nting is made too close, it will soon become necessary weed out a number of young trees, and the time and)enditure spent on raising them will be thrown away. 1appy mean should therefore be sought for.[1] Small nsplants should be put in, as a rule, closer than large s, not only because otherwise it would take longer form leaf-canopy, but because small transplants are ch more liable to suffer from drought or attacks of their nerous enemies than larger ones. Similarly, trans- nts belonging to slow-growing species should be put closer than those which start at a great pace, like ιk, certain *Eucalypti*, *Acaciae*, etc., and shade- iding species will also be all the better for not being wded out too early. In the case of plantations sisting of climbers, such as *Landolphia*, which, after king a start, will have to be trained horizontally on ports, the distance between the plants will have to much greater.

It may be useful to obtain the transplants from ural-grown seedlings in a neighbouring forest. se seedlings usually develop a very irregularly shaped ting apparatus, and it is chiefly with young seedlings ch have not yet had time to develop any considerable ts that transplanting is likely to meet with success.

The methods of raising plants from cuttings, layers, rhizomes have already been described in the pter on Nurseries, and there is nothing to add to n.

If there is a regular rainy season, the best time for ıting is at the beginning of this season. The plant- should not be done during a heavy downpour, when streams of water would convert the soil used for

[1] In the Tropics, moderate-sized plants put in for timber are commonly ed 6 ft. × 6 ft., according to the square pattern.

planting into liquid mud. The best planting weather is a constant steady drizzle, or, if this cannot be got, then a cloudy day following after rain. It must be borne in mind that in most plantations it is too expensive to resort to hand-watering after the plants have been put in, and that they should therefore be put into soil having a sufficient amount of moisture to supply the roots at once. In places where, owing to deficiency of rainfall or nature of the soil, artificial irrigation has to be resorted to, the planting season may depend on the time when an ample supply of water is available, and on whether frosty nights may occur. In the latter case, planting should not be started during that season. When the species to be planted is leafless for part of the year, the best time for planting is during the leafless season, as the roots have not to start at once in supplying the leaves and young shoots with water. In the Tropics there are so many factors to be studied that it is not possible to lay down any hard-and-fast rule, and the requirements of individual species in the locality must be studied.

After putting in leaf-bearing plants it is wise to *shade* them. In a previous chapter I have already stated that if leafy twigs are used they should not be of species the leaves of which drop off on drying and smother the young plants. Those whose leaves blacken and then fall off seem to be particularly bad. Certain stiff ferns do well, and also stiff wiry twigs. They should not be pushed in so close as to exclude air or light, and they may be put in sparingly on the side on which the sun's rays are not likely to reach them, unless the glare and reflected withering heat from the ground are strong. In frosty localities the young plants require most shelter from the sun's early rays, as frost-bite is due to the sudden heating of juices and consequent breaking of tender tissues in the plant. It is not sufficient to put in the shading, but it should be frequently examined, as the twigs or fronds bend down and are apt to suppress the plants, and, if they are wet,

rot them. This is particularly necessary after a vy fall of rain, when the weight of water bends m the shading material over the plants. In some ıtations, instead of shading with twigs or ferns, it y be advisable to raise a *nurse*-crop beforehand. s would usually consist of quick-growing trees with ght foliage. Such nurses, for example, are raised on ıo plantations, the trees most used being some species *Erythrina*, *Albizzia moluccana*, etc. In coco-nut ıtations in Ceylon native planters are in the habit aising shade crops of manioc or banana, but these e the drawback of being very exhausting for the soil.

Wherever weeds spring up readily, it will be essary to do a certain amount of *weeding*. In lon plantations, where the whole area has been red, it is usual to weed the whole over again. But does not seem to me to be really necessary, at any for plantations of forest trees. What is required is weeds should not invade the soil round the plants such an extent as to retard their development, ther this hindrance may be due to suppression he portions above ground or choking of the roots. this reason it is necessary to weed out round the ts sufficiently far to prevent this. Particular ntion should be paid to plants having creeping omes, to climbers, and to root-parasites. I have a whole field of young Ceara-rubber trees ruined a parasitic *Striga*, which was considered a harm- weed, while, all the time, it had been drawing its enance from the roots of the young plants.

In places where drains have been made, whether lraining water-logged soil or for carrying off surface er, the drains should be frequently inspected and ed of débris which have accumulated within them might cause them to get choked. This is especially ssary for drains on hill-sides, which are most liable et silted up.

However well kept a plantation and however success- t is, there will be some plants which will die during

the first year. In the same way, where sowings have been made, there will be some gaps in which the seed has not germinated, or where, if it has germinated, the young seedlings have sickened. If these gaps are inconsiderable, and if the species sown or planted which are still alive are still growing sufficiently close or are of a fairly quick-growing species to fill up these gaps, there will be no necessity to refill them artificially. But in most areas under reafforestation some refilling will be necessary. This is called *supplying vacancies*, and if plants are put in they are called *supplies.*

In sowings, the vacancies may be supplied by putting in fresh seed in the vacant spots, but if, over the rest of the area, the seedlings are not backward, it will be best to put in plants. In areas which have been planted it is usual to put in supplies.

Where these are put in, it is imperative to make them a success ; only strong, healthy transplants should be used which will be able to thrive on soil which has not been improved by one year's exposure. For this reason plants raised in supply-baskets are the best, as none of their root-fibres need be disturbed in planting. They may be more expensive, but it is better to have expensive plants sure to thrive than to have to go on supplying for several years.

In all areas under afforestation a watchful eye must be kept against inroads of fire, of destructive animals, and of plant parasites, especially of fungoid diseases. It is not sufficient to cut out unhealthy shoots ; they should be destroyed by fire, and it may even be necessary to take out entire plants and burn them, in order to save the rest from being attacked in the same way. In cutting out, jagged wounds should be avoided ; the wounds should be made clean and with a sharp knife, and coal-tar should be painted over them to prevent the ingress of destructive insects or fungi.

In comparing the relative value of direct sowing with planting, it should be first borne in mind that

whereas both seeds and very young seedlings are liable to suffer from a variety of dangers from the very outset, transplants brought in from a nursery or from the forest have already survived this most critical period of their existence and give a better prospect of success. Also, although direct sowing may be cheaper in the way of saving some of the expense on nurseries and in the preparation of the ground, some time must elapse before the seed germinates and develops into seedlings of the size which plants from the nursery have at the time of transplanting. The crop, therefore, takes longer to reach a marketable size, and there is thus a corresponding loss of revenue.

When a mixed crop has to be raised, it is much easier to obtain the mixture desired by planting, for even when seeds have been well mixed the heavier ones will have a tendency to sink to the bottom of the bag, and the mixture will thus become uneven.

In unfavourable soils and localities, particularly in those in which tender seedlings are liable to various causes of injury or to be kept back in their growth, planting is preferable to sowing, and this must be resorted to in moist or wet soils, as well as in those which easily dry up or are poor at the surface, and in all soils that are liable to be overrun with weeds. It will also usually give better results where the rainfall is irregular or limited to a very short period.

Sowing may give quite favourable results in localities where the soil is neither too dry nor too wet, where the rainfall is evenly distributed, and where there is not much danger from invading weeds. In soil which is rocky and covered with boulders it may even be preferable to planting, and it is also advantageous to resort to it for species which have sensitive roots which do not bear transplanting, unless basket plants are used. As planting requires more labour than sowing, the latter may also have to be resorted to where labour is scarce. But on the whole it may be said that planting gives better results than sowing.

CHAPTER VII

NATURAL REGENERATION: REGENERATION BY COPPICE

(*a*) *Regeneration from Stool-shoots.*—We have seen earlier, under definitions, that stool-shoots are shoots which have sprung from the stool of a tree after the latter has been cut down. These shoots may develop either from "dormant" or from "adventitious" buds.

Dormant buds are axillary buds which, in ordinary conditions, remain alive without sprouting, but which may develop into shoots in certain circumstances, such as by removal of the existing foliage, or by exposure of the woody axis to direct sunlight. Adventitious buds are all those which originate in any other place than the axils of the leaves.

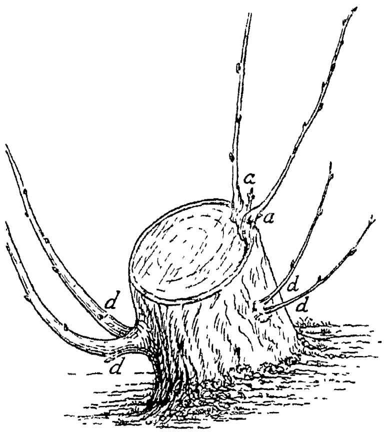


FIG. 68.

Probably the greater majority of stool-shoots are due to dormant buds. Young stool-shoots from dormant buds can usually be distinguished from those from adventitious buds, as they sprout outside the circumference of the stool, while the latter usually spring from a swelling (or *callus*) produced over the cambium on the top of the

stool (Fig. 68 ; *a*, shoots from adventitious, and *d*, from dormant buds).

Most dicotyledonous trees have, in a greater or lesser degree, the faculty of producing stool-shoots ; in some cases or in some places this faculty may be so slightly developed as to make coppicing hardly possible ; other species, on the contrary, reproduce themselves freely from coppice. Again, while several species will be able to produce stool-shoots up to an advanced age, there are others that will be unable to do so except while they

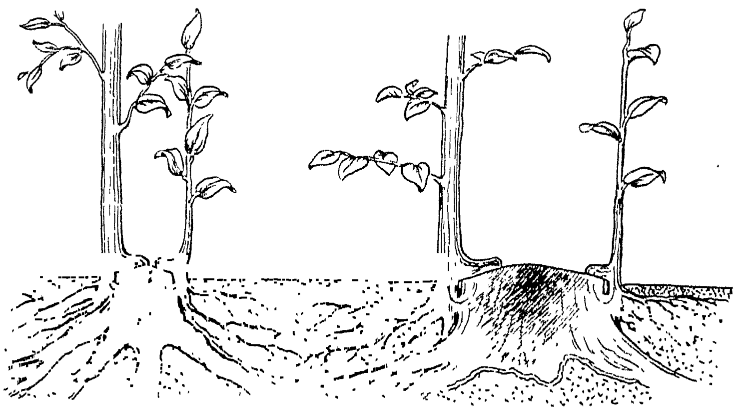


FIG. 69.

are comparatively young ; or it may be that if they are able to give out stool-shoots after passing that age, these shoots are weak and unable to develop into trees. Most coniferous trees are without the power to reproduce themselves from coppice-shoots.

As a general rule, it will not be advisable to attempt coppice when the majority of the trees in the wood are much above 60 cm. (2 ft.) in girth.

By cutting trees of comparatively small girth another advantage is gained, which is that there is less danger of decay penetrating into the stool-shoot than when large trees are felled, for the stool gets more quickly occluded by the foot of the shoot. A large

stool never gets completely covered up, and decay sets in from the centre of the stool and gradually spreads to the foot of the shoot (Fig. 69).

The nearer to the level of the soil that the shoots can be induced to spring, the more likely are they to develop independent roots (see Fig. 69 above), and the greater the probable longevity of the stools. When shoots spring on a high stool, they must depend for sustenance entirely on the stool; and if the latter decays in the centre, as must be the ultimate fate of most large stools, they ultimately stand on the rim of a hollow cup (Fig. 70), which is steadily getting weaker and less capable of nourishing the shoots. For this reason European foresters teach us that stools should be cut flush with the ground.

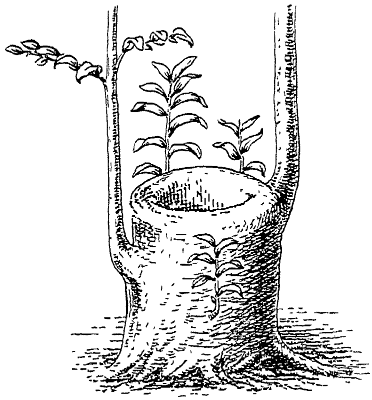


FIG. 70.

This rule can, no doubt, be followed in certain parts of the Tropics, such as have not great extremes of drought and rainfall; and where the sun does not exert too strongly a desiccating influence on the stools. In such places the woody part of the stool is apt to split and shrink and to tear itself away from the bark, thus breaking the cambium-zone. This can be mitigated to some extent by heaping earth and leaves over the stools, but not always; and it has been recommended that the stools be cut at 10 to 15 cm. (4 to 6 inches) from the ground. In places liable to floods, also, it has been found that stools which get covered with water die down; this was the case, for example, with stools of *Acacia arabica*, on the banks of the Nile, in the Sudan where the water rose up to about breast-height du

the trees in such a manner that their stools did not become submerged. The only precaution that can be taken is not to cut trees for coppice except those of such small diameter as will have a chance of having the wound covered up quickly by the growing shoots.

Another rule given by European foresters is to cut with the axe and to fashion the stool preferably into a flat dome shape, or, at any rate, not to make it hollow in the middle. The object of this rule is to avoid a spongy surface which would be given with a saw and to prevent water accumulating over the stool, a spongy surface and a hollow stool hastening the decay of the wood and the death of the stool. This rule still holds good for the Tropics; but where there are indifferent axe-men who chop at a stool and ultimately leave it much hacked about, it is a question whether a clean cut with the saw, made in a slightly downward slanting direction, is not better. I myself have found it to be quite satisfactory with quick-growing *Eucalypti* in the mountains of Ceylon. In the case of small poles the best implement is probably a bill-hook or one of the similar implements used by natives for clearing a way through jungle, such as *khookri*, *dah*, *catti*, or *machete*, with which a slanting blow is given close to the ground. With a little practice the young tree is felled at one stroke. The blow should be given outwards from the body; for, if given inwards, the impetus may carry the blade against some part of the striker's anatomy and cause a wound. If an axe is used, a heavy block of wood should be placed against the young tree on the side opposite to that from which the blow will come. This will not only make cutting easier, but will save the root-system from suffering from shock.

The best time for coppicing varies greatly according to species and locality. It may even happen that the forests are inaccessible during the best season. As a rule it may be said to be best shortly before the vegetation breaks out into renewed activity. This season is usually shortly before the burst of the principal rainy

season. But it does not always turn out to be so. Certain foresters have found the best time to be at the close of the rainy season, while others have declared the dry season to be the best. Much will depend on the intensity of the sunlight, the strength of scorching winds, the danger to young shoots from frost. A hard-and-fast rule cannot be made, therefore.

Stool-shoots are generally more shade-avoiding than seedlings of the same species. No doubt, in the Tropics, where the sunlight is much more intense than in temper-

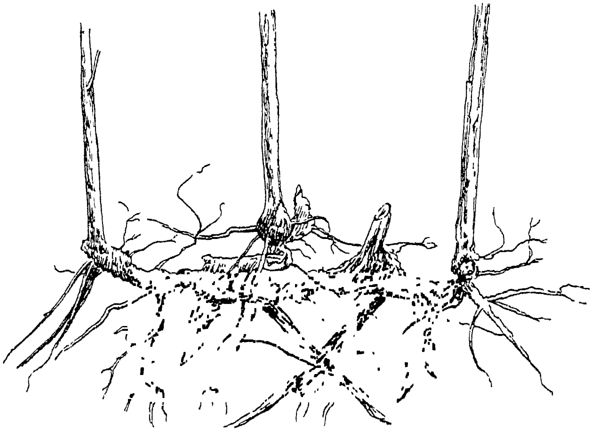


FIG. 71.

ate zones, they can stand more cover; but coppicing under complete leaf-canopy, especially when the latter consists of crowns of evergreen species, should be avoided.

(*b*) *Regeneration from Root-suckers.*—Many trees, having superficial roots, have the faculty of producing shoots from adventitious buds on the roots. These are called "root-suckers" or "root-shoots," and may be produced either during the lifetime of the parent tree (Fig. 71), where the roots are exposed or have been wounded, or they may spring forth after the parent tree has been felled. The natural order of the Leguminosae perhaps possesses the greatest number of species having

the faculty of throwing out root-suckers. The subject has not-yet received all the attention that it deserves; but recent observations in India have revealed the fact that a far greater number of species, among them Teak, possesses this faculty than was hitherto suspected.

These root-suckers possess several advantages over stool-shoots. They are better for filling an area evenly, for they come up singly, or in small groups along superficial roots,[1] while stool-shoots arise in bunches on the stool; they are able to develop an independent root-system, and not being close to the stool they run less danger from foot-rot. Also, in some cases, as when the parent tree is in the open and its roots exposed in places to direct sunlight, root-suckers will spring up before the parent tree is felled and derive nourishment from it.

As a crop of root-suckers would be obtained largely by the felling of parent trees, by which process direct sunlight would be also brought to bear on the superficial roots which show up on the surface of the soil, it is evident that a coppice composed entirely of root-suckers is hardly to be obtained, and that there will usually be a fairly even mixture of stool-shoots and root-suckers. The number of the latter can generally be materially increased by grubbing up the soil and wounding the superficial roots, wherever these come near the surface of the soil.

Stool-shoots and root-suckers are, at first, quicker growing than seedlings, although they are not always capable of attaining the same dimensions and the same age, at least those which come from any but young stools. For this reason, such a crop is generally raised for the purpose of obtaining, in the shortest time possible, wood of small dimensions for which there is a demand, such as firewood, mine-props, scaffolding- or telegraph-poles, wood for paper-pulp, etc. When the shoots have arrived at the required dimensions, they are

[1] An instance is given by Mr. G. M. Ryan, in vol. xxx. No. 10 of the *Indian Forester*, of root-suckers of *Albizzia Lebbek* being found at a distance of 100 feet from the parent tree.

coppiced again, and their stool-shoots and root-suckers will furnish the next crop, which will be again coppiced at the end of the next rotation, and so on.

For how many rotations stool can be added to stool is a matter of which we have, at present, no knowledge. It will no doubt depend largely on the species and on the length of rotation, and consequently on the vitality of the stool, and on that of the shoots which it produces, and which will in turn give the next stools. But it is clear that this cannot go on for ever, and that a time comes when the stool becomes weak and cannot reproduce more shoots. It is therefore necessary to provide for an admixture of trees sprung direct from seed whose stools can replace those which are losing their power of reproduction. The same remarks apply, but probably in a lesser degree, to root-suckers. This admixture may be obtained either artificially, by sowing or planting, or naturally, by keeping standards to stand over the coupe and provide seed.

Standards are kept not only as seed-bearers, but also to provide timber of larger dimensions than that which is obtained from the majority of the crop. In *simple* coppice, as we have seen under definitions, either no standards are left standing, or they are only left for one extra rotation; while in coppice *under standards* they may be left for as many rotations as may be required to develop their timber to the size at which it will be of the greatest use to the owner of the wood. Standards, if selected to produce timber, will be chosen from among the most useful species; whatever their object, they will either be sprung direct from seed, or, if they are coppice-shoots, they should not originate from old stools or roots, the decay of which would affect their vitality.

In the Tropics, wherever the locality is subjected to a great drying heat or to parching winds, simple coppice without any standards whatever will not be advisable. This is more especially the case where the rotation is short and the soil would be exposed and subject to deterioration at frequent intervals; also in

places which are apt to be invaded by noxious weeds as soon as direct sunlight is let in.

The number of standards to be left per unit of area will depend on the species and the locality. Although stool-shoots are more shade-avoiding than seedlings, it is necessary, more in the Tropics than elsewhere, to protect soil and young growth from climatic influences. Experiments made in Oudh with Sāl coppice[1] showed that 60 standards from 18 in. to 3 ft. in girth per acre (150 standards from 45 cm. to 90 cm. in girth per hectare) provided sufficient protection for the undergrowth.

The length of the rotation will depend on the rate of growth of the coppice-shoots and on the size which they are destined to attain. In the Tropics, as a rule, it will probably vary between eight and twenty years; but no rule can be fixed.

When strong winds are to be feared the coupes should be made comparatively narrow in comparison to their length, the long side being at right angles to the prevailing wind. It is also best to start the felling at the leeward end of the forest, that which remains standing not only affording shelter to the young crop but supplying a certain amount of seed, which is blown into the coupe by the wind. When the last coupe reaches the windward end of the forest, a wind-belt should be kept to protect it.

On steep hill-sides the coupes will also be made narrow, also horizontal to prevent erosion from surface drainage. It will be best, after leaving wind-belts on ridges and spurs, to make the first coupes at the top of the slope. This will save young growth from being damaged by fellings made above them.

(*c*) *Pollarding.*—This is merely a variant of coppice from stool, and consists in the periodical coppicing of the crown of a tree in order to obtain a crop of long flexible shoots, such as are used *e.g.* in basket-making. This is first effected either by the removal of the entire crown

[1] S. Eardley-Wilmot in *Indian Forester*, vol. xxv. No. 7, App.

or of the greater part of all the principal branches (Fig. 72), after which the shoots which are given out are cut back at intervals of one to two or even more years.

In Europe the willow is subjected to this treatment in order to provide withes for basket-making or hoops for casks. In the Tropics several species might be treated in the same way for the same purpose, or for that of yielding leaves for fodder or for manure, or for raising silkworms. In places where canes, bamboos, or woody twiners are abundant, it is probable that this method of treatment for basket-making will not be in much request.

FIG. 72.

(*d*) *Regeneration from Culms.*—The regeneration of bamboos comes under two heads, viz. by seed and by culms from the rhizomes. When a bamboo clump seeds it dies, and further production of culms must be effected by the seed which it sheds. This seeding may take place after a considerable number of years have passed, and in the meanwhile the annual production of a certain number of culms from the rhizomes has to be effected.

Bamboos may be classed into two categories, viz. those which give out long rhizomes and which produce culms at appreciable distances from one another, thus forming naturally open clumps, and those with short thick root-stocks, giving out culms in somewhat dense masses together, forming close or "tufted" clumps.

With the former clumps, what is required so as to obtain a continuous yield is to avoid cutting the shoots of the year, so as not to check the vitality of the rhizomes at their growing point, and to leave a sufficiency of older culms, the leaves of which will elaborate the sap and keep up the vitality of the clump, or of a particular radial group of rhizomes.

With tufted clumps, where all the culms spring within a restricted area, additional care has to be paid to prevent the clump from becoming congested, that is, the felling has to be made in such a manner that the new rhizomes, in their development, will not be checked by being arrested by the dead rhizomes appertaining to culms which have already been cut, or by the mass of old culms outside. This checking may lead to the new rhizomes being developed towards the centre of the clump, where, the ground being already occupied by a dense mass of older or dead rhizomes, the new ones are forced upwards and produce culms which are hemmed in by those which already exist. Of all bamboos, that for which there is the greatest demand is probably the *Dendrocalamus strictus* of India, and it is with this species that most experiments have been made in tropical and sub-tropical forests. One method of treatment which has apparently yielded good results consisted in cutting about one-third of the total number of culms in a clump in such a way as to leave the remainder of the culms well spaced, no culm being cut at more than 6 in. (15 cm.) from the ground. The culms which are less than one year old are not cut.

As this system was found to be applicable only to comparatively small areas, owing to the amount of supervision necessary, another system was introduced for larger areas. In these, the bamboo forests were divided into blocks; some of these blocks were liable to heavier working, owing to their being closer to industrial centres. In these blocks no working is allowed for two years, and in the third year none of the shoots of the year are allowed to be cut, while at least four or five of the

maturer culms have to be left in every clump to keep up its vitality. In blocks which are not subjected to the same intensity of working, the same rules apply, but they are thrown open to working every other year.

The question as to how near to the ground the culms should be cut has not yet been solved to the satisfaction of all experts. If they are cut close to the ground, the

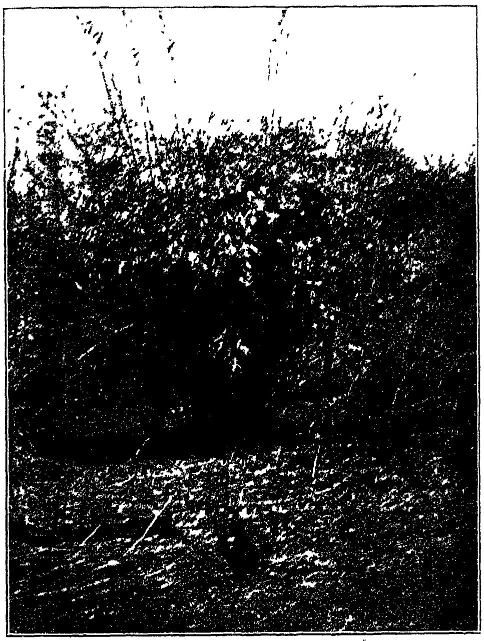


FIG. 73.—*Oxytenanthera abyssinica* bamboo, showing young culms in centre of the clump.

working in after years, no doubt, becomes easier, and the culms are not crowded at the outset. On the other hand, it is maintained that as the cut culms die down, from the place where they are cut downwards, at the rate of one internode per annum, their rhizomes remain alive until death has reached the lowest internode, and that thus the general vitality of the clump is contributed to by the stools of culms which have been cut down,

provided that these stools consist of several internodes. The question has never been definitely settled, although it is generally admitted that in congested clumps, in which the culms are crowded together within a small compass, culms should be cut close to the ground in order to afford more growing room to the others.

Grazing should be excluded from bamboo forests under regeneration by culms, as cattle greedily devour the young shoots. Elephants are particularly destructive, as they not only break up the clumps, but also uproot and upset them to let their calves reach the tenderer culms which pierce through the crown of older culms and emerge in its centre (Fig. 73).

CHAPTER VIII

NATURAL REGENERATION BY SEED

ONLY few of the various methods in which natural regeneration can be effected have, as yet, been applied to tropical forests; it is therefore not possible to describe from practical experience how their application has affected different classes of these forests, and European experience must be depended on in giving the descriptions. A large portion of the forests in the Tropics which have been taken under scientific management have suffered during centuries of ill-usage, and the efforts of the administration have been directed chiefly to leading them back to a more normal condition.

(*a*) CLEAR-FELLINGS

In clear-fellings all the trees standing over the area are removed at one operation, and the regeneration depends partly on seed fallen from trees on the area before they have been felled, and partly from seed brought in from outside by natural agency, such as by wind, by gravitation if the fellings are on a slope and below seed-bearing trees, by water (as *e.g.* by floods or by the action of tides or by surface drainage), or by animals in the case of seeds enclosed in edible pulp.

One of the first conditions for successful regeneration is that the species whose seed is thus distributed over the area should be shade-avoiding and capable of standing exposure. On the other hand, the great draw-

back is that it is rare to obtain at once a full crop of seedlings, and that, in the meanwhile, the soil deteriorates from exposure and gets covered with weeds and other invading plants which suppress germinating seedlings.

An essential condition is also that the whole crop should be marketable. With such crops as are composed of a variety of different species, only a small portion of which can be sold, such a system of fellings is inadmissible, as the coupes would remain encumbered with a mass of dead wood, which would become the host of a number of injurious insects and fungi, and would be the cause of constant danger from fire.

There are three methods in which clear-fellings can be carried out, viz. that of *Clearings*, that of *Cleared Lines*, and the *Well* Method.

(i.) In the *method of clearings* no special consideration is given to the shape of the coupe, the area which has to be regenerated in any given year, whether it be of regular or irregular outline, broad or narrow, being cleared of trees. Such an area becomes exposed at once to all local climatic influences such as sun, wind, rain, and radiation, and the species which spring on it have to battle from the very outset with all the adverse factors which may present themselves.

The best time for making the fellings would be when the trees over the area to be felled bear a ripe crop of seed. This would give the future generation a better chance of coming up quickly, and the soil would be given some measure of working up by the felling and transport of the timber. Some species seed freely every year, while others may seed at regular or irregular intervals, sometimes several years passing between two good seed years. When it is possible to foresee these good seed years the fellings should be fixed for them.

If the seed-fall depends largely on trees outside the area, it will be best to make the fellings against the wind in order that the seed may be blown by the wind on to the coupe from the still standing stock. On hill-sides,

after leaving wind-belts on the ridges, the fellings should first be made in the upper parts of the slopes, as, if begun at the bottom, although regeneration would be better encouraged, the young crop of seedlings would run the danger in subsequent years of being injured by the fellings made above them, and by the consequent export works.

The great advantage of this system, apart from its simplicity, is that the fellings are concentrated and compact, and that supervision is easier and the extraction of timber is much cheaper than when the fellings are more scattered.

On the other hand, success in regeneration is so problematical or so irregular and long deferred that even where a sale for the whole out-turn is obtainable, it is a method which cannot usually be commended in tropical forestry. I have never seen it employed by foresters in the Tropics, but the effect of such an operation can be studied in places where shifting cultivation has made gaps in forest lands. Among these effects the following may be quoted:—

The whole area got covered with a dense growth of grass or bamboos which occupied the soil with its rhizomes, *e.g.* by *Imperata arundinacea* and *Ochlandra stridula*; or the area was invaded by dense shrubs, usually thorny, and by creepers, through which, after an interval of many years, more arborescent growth began to struggle; or a poor growth of ferns and under-shrubs, such as *Gleichenia* and *Hedyotis*, came up, and left the soil unimproved and sterile as far as tree growth was concerned; or the soil remained bare, fissured, and hard baked, and produced nothing but a few stunted shrubs and under-shrubs.

In a few cases a quick-growing mass of soft-wooded trees covered the area, such as *Trema* and *Macaranga*, and under their shelter seedlings of more valuable species sprang up. This was on good soil and with well distributed rainfall.

The above examples are hardly sufficiently encourag-

ing, and the only case in which the method can be followed advantageously, provided there is sufficient demand for the material, is when a bamboo forest seeds gregariously, as happens with several species of bamboos.[1] All the clumps die after seeding, and if the culms can be cut down and removed, not only does the young crop of seedlings get a better chance of coming up, but a very considerable danger from fire is also removed.

(ii.) The aim of the *method of cleared lines* is to remove some of the dangers appertaining to the method above described by giving side shelter to the coupes, and by making them so narrow that seed from the standing crop may be easily distributed all over the area.

The fellings are made in narrow strips cleared through the forest, corresponding strips of standing forest being left untouched between successive coupes. The cleared strips are made of a width which is usually not much greater than the height of adjoining forest trees; while the width of the strips left standing is either the same as that of those which are cleared, or a multiple of that width in places which are much exposed to violent winds or to erosion.

The direction given to the strips is governed by the direction of the prevailing winds, especially of those prevailing at seed-time, by the configuration of the ground, and by the course of the sun.

As regards the wind, it is most advantageous to cut

[1] It must be confessed, however, that sometimes Nature has a way of laughing at the obstacles which delay natural regeneration in large open spaces. In Ajmere the mere closing of certain areas to grazing and preservation against fire has led to the springing up of forest [illegible] of which was no doubt from stool-shoots or root-suckers which had been annually killed down to the ground level. But in the Sudan, in the Province of Dongola, the riparian lands of which along the Nile had been subjected to a high degree of cultivation, the invasions of the hordes of the Mahdi and Khalifa cleared the country of population and herds, and left the ground untilled. Here, although the rainfall is not above 1 in. per annum, all the arable lands got covered with a dense growth of *Acacia arabica* and *A. Seyal*, and this was the condition they were found in when the British and Egyptian troops again took the country. The same thing happened in parts of the Berber Province and near the upper Blue Nile, where the rain crops were cultivated some way inland: the population was sent away to Omdurman, and the fallow fields, many square miles in extent, got covered with an almost pure forest of *Acacia Seyal*.

the lines at right angles to the direction of the wind which blows during seeding time ; but if, by giving such a direction to the cleared lines, there is a danger of letting in violent winds at other times which might do damage to the young crop, and perhaps even to the portion of the older crop which has been left standing, it is wiser to let these winds govern the direction of the lines. In following this rule, however, it is essential that the distribution of seed over the coupes be not made impossible ; and if it be not practicable to give to the lines such a direction as will not only afford the necessary protection but make regeneration possible, another method of regeneration must be adopted.

In mountainous countries the direction will depend partly on the gradient, and partly on the local direction of the wind. On steep slopes the lines should be made horizontal in order to prevent erosion ; on gentle slopes, on the contrary, it will probably be more advantageous to make them at right angles to the contours. By so doing there will be less risk of injury to the standing crop adjoining the coupes, and extraction of timber will also be made easier.

As the direction of the wind, in hilly country, may be deflected by protruding spurs, or may be led into a different direction through gaps in the range, it is necessary to study these local conditions before the direction of the lines is finally fixed upon.

The course of the sun has also some influence in the selection of a direction for the lines. Broadly speaking, as the sun rises in the east and sets in the west, they should be made north and south, in order that the seedlings in the lines may have shade during the greater part of the morning and afternoon. According to the slight variation from this course which the sun may run at the time when the seedlings are in their most delicate state, the lines may be made to be deflected from the north and south direction to one which will give shelter to the seedlings for as long a portion of the day as possible.

In localities where frosts are to be feared the lines should not be cut so as to let the early sun strike the seedlings, which might otherwise suffer from frost-bite. The same rules as those for the preceding method also apply here as regards making fellings against the wind and from the upper parts of the slopes.

It is often necessary to leave wind-belts not only on the outer edge of the forest and at the extremities of the lines, but along ridges and on spurs wherever the lines cross them.

It is evident that this method can only be used where the whole out-turn of the coupe can be utilised. Experiments have also shown that the lines are apt to get overgrown with grass, weeds, or creepers, and that it is generally only when a quick-growing crop can establish itself that other more valuable species can spring up under them.

Cleared lines offer tempting grazing and browsing grounds, close to cover, to wild animals, and are therefore not suited to the localities where these abound; for not only will seedlings and saplings be browsed down but they will be trampled down, and will be barked by deer when stripping the velvet from their antlers.

(iii.) The *well method* consists of small clearings, up to about one-fifth of a hectare (half an acre) in extent, made here and there all over the forest. The advantage of this method is that the area cleared is closely surrounded by standing forest, and that seed has the best chance possible of being distributed all over the soil, and also that the young growth is sheltered on all sides. The danger from grass and brushwood is therefore somewhat reduced, as seedlings may spring up more quickly and occupy the ground. On the other hand, the operations are more costly, as they are scattered over a wide area. It is a method which might suit certain species which require light overhead and side shelter, such as *e.g. Berrya Ammonilla.*

Taken as a whole, clear-fellings are rarely suitable for scientific regeneration of forests in the Tropics. The

dangers from a burning sun, drying winds, torrential downpours, plant enemies whether animal or vegetable, are, as a rule, too great to allow of sudden removal of the leaf-canopy. With mixed forests especially, it is frequently the case that there is a sale only for the more valuable species, and the dangers arising from masses of dead wood lying about the coupes are too great to be risked.

(*b*) Partial Fellings

Regeneration by partial fellings can be effected *uniformly* over the area to be regenerated, successive operations being carried out by which the cover is gradually removed as the young crop germinates and establishes itself, and *irregularly*, by taking out mature or deteriorating trees here and there, where they require to be removed, and replaced by young growth.

(i.) *Uniform Fellings.*—These comprise three series of fellings, which are called respectively *preparatory-*, *seed-*, and *after*-fellings.

Preparatory-fellings have for object to accustom the trees left standing to bear isolation, to bring light in sufficient quantity on their crowns, to encourage the production of seed, and to prepare the soil, where necessary, for the reception of seed.

If the trees which are ultimately to become the seed-bearers are exposed too freely all of a sudden, there is danger that they may be thrown down by any sudden storm; they must, therefore, be gradually accustomed to stand by themselves, and this is done by gradually removing their neighbours. The number of preparatory-fellings which are necessary for this purpose will largely depend on the species which is to be thus isolated. If the species has a weak root-system and a large crown, the isolation has to be more gradual than with species which stand firmer in the ground and have not too large crowns. For this reason, the trees selected for retention should have for their species not too large a

crown. A too narrow crown has the drawback of not being able to bear much seed.

As regards the preparation of the soil for the reception of seed, in order that the latter may be offered the best conditions for germinating, and the seedlings for establishing themselves, the gradual opening of the leaf-canopy may become necessary to effect this.

If the layer of humus and partly decomposed vegetable débris is so thick that the rootlets of the germinating seedling cannot reach the mineral soil within a short time after germination, it is necessary to let in direct sunlight and to admit the free circulation of air in order to reduce this upper layer to a favourable condition for germination and development of the young seedling. This is done by opening the leaf-canopy to the degree which is required, and this degree will be attained more or less quickly according to the nature of this top layer and to the locality; viz. quicker and heavier cutting is required where decomposition is slow, and lighter where enemies to the young seedlings in the shape of weeds and creepers would also be encouraged.

On soils which have no covering of vegetable débris, such as are very frequently found in the Tropics, and where the intense sunlight penetrates through the densest leaf-canopy and reaches the soil, preparatory-fellings would probably not improve the latter, and they must be restricted to what is necessary for training the seed-bearers to stand isolation and their crowns to bear a good crop of seed. Where the leaf-canopy is already open, these fellings will not be necessary.

The best time for making these fellings is generally shortly after the trees have reached their maximum height. They are then in their fullest vigour. It happens, however, that at that time they are often still far from having reached exploitability, and the fellings have to be deferred till later when they are no longer in the very best condition for producing the highest quality of seed. Care should be taken, therefore, to select for retention the finest and soundest of the trees. In a

mixed forest the seed-bearers should consist of a due proportion of trees belonging to the most valuable tree species, but the selection should by no means be limited entirely to them, other species being also kept in sufficient numbers to provide for a favourable mixture in the future crop.

In places where the soil is poor or overrun with weeds it may be necessary to help the preparation of the soil for seed by giving it a slight wounding with hoes, rakes, or similar implements.

The removal of undergrowth may be desirable, but not always, as it often offers a very necessary protection to the soil. Many tropical species like low cover to begin with, and in dealing with these the removal of undergrowth should be limited to the cutting of creepers, shrubs, or under-shrubs forming too dense a matting over the ground. In places where large climbers have established themselves over the crowns of the trees, climber-cutting may not only let in sufficient light and air, but the crowns of the trees, having become free from the superincumbent masses of vegetation, will also become more capable of bearing seed. In forests the lower tier of which is entirely taken up by a dense mass of bamboos, the problem is a very difficult one, unless there is a sale for all the bamboos that can be cut. Bamboos die down when they have seeded, but this seeding generally occurs only at long intervals, and the seeding may not be coincident with preparatory- or seed-fellings. The only remedy which has been recommended so far has been to let in fire into the forest in order to destroy the greater part of the bamboos.[1] It is a remedy which it is not easy to recommend, owing to the damage which would be done to the rest of the growing stock. There is no doubt that since fire protection has been successfully carried out in certain parts of Burma, bamboos have multiplied, and in so doing have prevented the natural reproduction of other more valuable species.

[1] Since writing the above I have also read that the grazing of tame elephants in such areas has been recommended.

It is a question, therefore, whether the benefit derived from fire protection in these localities is not nullified by the harm done by the invading bamboo. The matter is now being closely studied, and, until definite results have been obtained from the observations, it will be advisable to go cautiously before resorting to fires. A similar difficulty arises in forests where the undergrowth consists of dense masses of such shrubs as *Strobilanthes*, which flower only once in seven to twelve years and then die down. With such the only thing is to wait for these seed years, and then to retard the next growth of these quick-growing under-shrubs by cutting them back while in their young and green stage.

After crowns of trees and soil have received the necessary preparation for the shedding and reception of seed, that is to say, probably after a couple of years, the *seed-fellings* are begun. These are destined to let in still more light to stimulate the germinating seedlings to establish themselves. At the same time, a sufficient number of trees are left to provide the necessary shelter against sun, wind, and rain, to prevent the too quick development of invading weeds, and to keep out other enemies. Where the seed is light, grass and weeds may prevent it from reaching the soil, and the fellings must be made light and often repeated. With shade-enduring species the fellings should also be lighter than with shade-avoiding species. In selecting the trees for removal, suppressed and ill-grown trees must first be taken, and also trees belonging to inferior or less valuable species, if they are more numerous than the more valuable kinds. If the trees whose progeny it is most desirable to encourage have light seed, the trees first removed should be to leeward; if it is heavy, the opening of the leaf-canopy should be close to the parent tree, and below it if on a slope. If the seedlings require low shelter at first the shrubs or under-shrubs will be preserved, and if they require side shelter the removal of a tree here and there will be sufficient at first. In most cases one seed-felling will not be sufficient, and it will

be necessary to repeat them in successive years, or, if good seed years are at intervals of two or more years, at intervals regulated by these seed years, until the seedling crop is complete.

Once the seedling crop is complete, it is necessary to accustom it gradually to stand climatic conditions, and this is effected by a series of further fellings known as *after-fellings.* By means of these the remaining cover is removed in successive operations until no trees remain over the young crop, except under special circumstances, when a few of the very finest trees, still in full vigour of growth, are reserved to stand for another period and allowed to attain special dimensions for timber.

French foresters divide these after-fellings into two kinds, viz. "coupes secondaires," by means of which the seedling crop is gradually trained to stand exposure, and the "coupe définitive," during which all the remaining overhead cover is removed, except perhaps the few standards which are left as stated above.

The number of after-fellings made will depend on species and locality. In places where there are violent winds or a scorching sun to be feared they must needs be light and often repeated, and shade-enduring species also require a more gradual removal of the cover.

It will be seen from the above remarks that the aim of the forester is to create a crop of uniform age all over the area over which these fellings are carried out. If this is obtainable all the trees grow up together, and owing to their uniform growth the timber obtained is also of a uniform quality, and there is a better prospect of obtaining cleaner timber than when the growth is irregular; for, under the complete leaf-canopy which is maintained, the lower branches die off before they have attained a size to form knots in the wood, this process going on until the trees have attained their maximum height. The grain of the timber will also be straighter and the number of trees with twisted fibre comparatively rare. The system is best suited to species which grow

gregariously, or to such as have an even rate of growth, or which can accommodate themselves to growing into a storied forest, some of them reaching the upper tier while others are growing in a lower tier, filling up interstices below the gaps in the leaf-canopy of the upper tier. It is not suited to places having extremes of climate, especially violent winds, as in such places the wind enters into the gaps made by the regeneration fellings, and is apt to play havoc with the trees which have been left standing. Neither is it a suitable system where the ground is at once invaded by weeds as soon as a gap in the leaf-canopy is made.

There are three recognised methods of carrying out these uniform fellings, viz. by the *Shelterwood-Compartment* Method, also called the *Compartment* Method, by the *Strip* Method, and by the *Group* Method.

(*a*) In the *shelterwood-compartment* method the respective regeneration fellings are carried on in their proper order simultaneously over the whole of an area (or compartment) to be regenerated. Thus, in a forest, as each subdivision or compartment approaches in its turn the exploitable age, it is treated over the whole area first with preparatory-fellings, if these are needed, then with seed-fellings, and finally with after-fellings.

This method, which is adopted in several European forests, has the advantage of simplicity. Each compartment is destined to become a uniform wood, and the regulation of the struggle for existence among trees of practically the same age will be simplified. On the other hand, it is rare that the stock is so uniform that the regeneration fellings are needed over every part of the area at one and the same time. It thus becomes necessary to make them in some places too early, and in others too late, and the best results are not obtainable.

With these fellings, as well as with clear-fellings, it is necessary that the whole out-turn be marketable, otherwise the operation may not only result in a financial loss, but the ground will be covered with a litter of dead trees, if it can be so called, which will

serve as a breeding-place to thousands of noxious insects and fungi, and will be a constant source of danger from fire.

(*b*) The *strip* method is a modification of the preceding method, just as the method of cleared lines is a modification of the method of clearings. The regeneration fellings are carried on successively over long strips cut through the area to be gradually regenerated. The strips are, in fact, long and narrow compartments, in each of which the necessary regeneration fellings are carried out in their turn. Thus when the preparatory-fellings, if any, have been started in one strip and the seed-fellings are begun, preparatory-fellings are started in the adjoining strip. When these are successfully effected, after-fellings will be started in the first strip, seed-fellings in the second, while preparatory-fellings are begun in a third strip adjoining the second, and so on. Sometimes preparatory-fellings are made several strips ahead in order to hasten regeneration, which might otherwise be somewhat slow in being obtained.

There is no limit to the length of the strips, but if a sufficient area cannot be covered by them they may be started at two or more points in the forest, care being taken to leave a sufficiency of untouched forest between the different sets of strips.

The width of the strips is usually not much greater than the height of the trees, but it may vary according to species to be regenerated and to locality. Shade-enduring species, and those which require side shelter more urgently when young, will require narrower strips than shade-avoiding species, especially those whose seed is light and winged and can be carried a considerable distance.

As this method is chiefly employed in windy localities the strips are cut as nearly as possible at right angles to the prevailing winds, and they should be started at the leeward end of the forest, unless the condition of the forest require that they should be

started in another place which more urgently requires the regenêration fellings. In this case the fellings will merely be made against the wind, the second strip being to windward of the first, and so on.

At all places where the ingress of winds is to be feared, such as on exposed ridges or on the outskirts of the forest, wind-belts should be left.

Fig. 74 gives an example of a forest, in compartments Nos. 1, 2, and 3 of which strip fellings have got

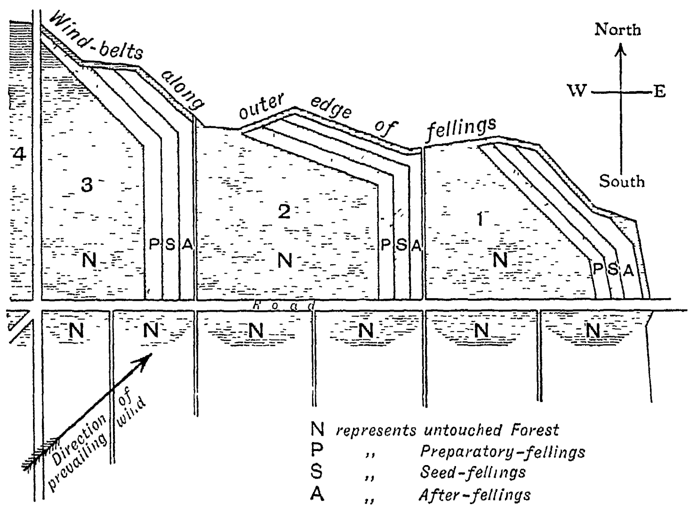


FIG. 74.

as far as the first three strips, after-fellings being in progress in the first strip, seed-fellings in the second, and preparatory-fellings in the third. As the prevailing winds come from the south-west, the fellings have been begun in the north-east corner of the forest, and the strips have been laid out in such a way as to assist the shedding of seed from trees in the area which has been left untouched and to protect the young seedlings from the wind when the cover gets removed. The outer edge of the fellings has also been protected against shifting winds by means of a wind-belt.

This method has the advantage over the compartment method of giving lateral shelter to more delicate seedlings and saplings even after the after-fellings have been completed. On the other hand, the length and narrowness of the lines make the working and supervision more costly.

(*c*) In the *group* method the regeneration fellings are carried out over no defined areas, but here and there over the portions of the forest the component trees of which are reaching exploitability, or belong to such species as require to be given a start over others in natural regeneration.

In a forest, however uniform at a casual glance, it will be found after a more careful examination that, owing to conditions of soil or from other causes, certain portions are more advanced than others and more ready for regeneration fellings. In a mixed forest, even of practically the same age, different species have different rates of growth and reach exploitability at different times; the forest in consequence becomes irregular, and this method becomes a more natural one than either the compartment or the strip methods, which ride roughshod over these differences and compel the forest to adapt itself as best it may to the treatment which is given to the whole area. In the case of an irregular forest of uneven age, the first two methods are even less suitable to its requirements. To such the group method is much better adapted, as the fellings are only carried out where they are required.

To illustrate this method, Fig. 75 represents a block of forest in which the points marked *a* are found to be the most suitable for starting the regeneration fellings. It may be that at these spots there is already a number of seedlings (*advance-growth*) which have sprung up unaided. If so, the fellings may at once partake of the character of seed-fellings, or even of light after-fellings if this advance-growth is sufficiently abundant or well established. But supposing that preparatory-fellings are needed, when these have been

effected, it will usually be found that the light admitted has made it possible, at the same time as making seed-fellings at *a*, to start preparatory-fellings in the surrounding belts of forest, marked *b*. Simultaneously with these, other spots marked *d* will also be found to be ready for preparatory-fellings. When the spots marked *a* are ready for after-fellings, those at *b* and *d* will be also ready for seed-fellings, and the surrounding forest, marked *c* and *e*, will be ready for preparatory-

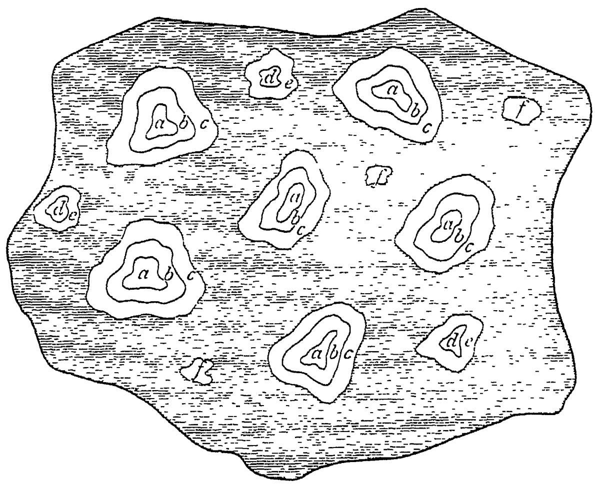


FIG. 75.

fellings, as also other spots in the forest, marked *f*, and so on until the whole area has been gone over, and a new and necessarily irregular crop, but uniform within each respective group, has taken the place of the old.

The drawbacks of this method are that the fellings are scattered over smaller or greater groups over a large area, that, consequently, fellings, transport, and supervision are more difficult and costly, and that there is more risk of injury to the adjoining crop. The outturn of timber will also be less regular than in either of the preceding methods.

Although the examples given above for the various

methods of uniform fellings might lead one to understand that preparatory-, seed-, and after-fellings have the same respective durations, such is by no means always the case. The seed-fellings, more especially, are likely to take longer than the other two, and it is often necessary to keep portions of the area under seed-fellings for a further period until the seedling crop has established itself thoroughly. In the same way preparatory-fellings must not give way too easily in places threatened by invading growths inimical to those which it is desired to rear, and after-fellings must be more gradual over delicate saplings unable to be suddenly exposed to climatic influences or in more exposed situations.

In the Tropics we have, as yet, nothing to guide us in estimating the time required for making these regeneration fellings. In France they are usually estimated to take about forty years.

Uniform fellings can only be employed in places where there is a market for all the out-turn from the coupes, and it is for this reason that foresters in the Tropics have been slow to employ them; for the demand is usually for only a few kinds or classes of timber, and where small wood only is required the woods are coppiced.

(ii.) *Irregular Fellings.*—These are comprised in the method known to French foresters as the method of *Jardinage,* a term also adopted by some British foresters, or as the method of *Selection-fellings.* This method consists in removing single trees here and there as they reach the exploitable size, or are on the decline, or are found to be unsound, and to let the regeneration take place in the gaps made by the felling with the help of seed shed by the adjoining trees. It may also consist in removing trees standing over advance-growth composed of seedlings and saplings of valuable species. Where the tree standing over advance-growth of valuable species belongs itself to a species of no local marketable value, its removal is sometimes

dispensed with, and it is killed by girdling when that is possible.

The result of such a treatment will be a forest of very irregular character, consisting of trees of all sizes and ages, from the seedling to the mature tree.

The advantage of this method is that it is simple, and does not require such skill on the part of the forester as the uniform methods. The gaps made in the leaf-canopy are small and more easily filled, and, in consequence, not only does the soil remain more uniformly protected, but it becomes more difficult for violent winds to enter and cause damage. For this reason it is invariably adopted in exposed situations.

Another advantage—which, however, may turn into a great disadvantage under certain circumstances—is that in a mixed forest, composed only partly of marketable species, it is not necessary to fell the whole crop, as in the case of uniform fellings, but the felling may be confined to those species for which there is an immediate sale. The danger is that by this removal of valuable species sufficient care may not be given to a renewal of the supply by regeneration, and that the stock gradually gets impoverished of valuable species until, at last, none remain. It is, therefore, necessary to see whether there is a sufficiency of trees of valuable species left standing close by, and preference should be given to those standing over advance-growth of the species which it is desired to rear. It may happen that advance-growth may be standing under cover of inferior species for which no market can be found. In this case the necessary amount of light may be given by killing the latter by girdling. It will be found, however, that there are several species which remain alive, and some even which continue to grow vigorously after girdling. For these there is no other way of disposing of them except by felling. At the same time, girdling on a large scale, and felling and leaving trees to rot where they have been felled, constitutes an additional danger to the forest, as the dead

and dying trees become the hosts of numbers of destructive insects and fungi, and, in case of a forest fire, feed the flames and add to their intensity. They may even be the cause of repeated forest fires, for sometimes trees which have been set alight will smoulder for months on end, and provide the means of starting other fires later on. In such forests, therefore, it is best to make such operations with a light hand and to pass over the same place oftener.

Trees grown under the selection method are less likely to give first-class timber than those grown under one of the uniform methods. The forest, as has already been stated, consists of trees of all sizes and ages; large trees may be standing close to small ones, and part of the bole remaining exposed, the lower branches on the exposed side do not die off but, on the contrary, develop to a large size, and not only is the growth of timber stronger on that side of the bole, thus forming uneven rings of growth and consequently uneven grain and uneven strength in the timber, but large knots are formed which impair its quality. There is also more risk of twisted fibre in the timber, owing to the action of the wind on the exposed portions of the crown. The method also presents a good many difficulties when the forest is a mixed one, largely composed of shade-enduring species, but the most valuable shade-avoiding.

Nevertheless, owing to the simplicity of the method and to the dangers which are met with from exposure of the soil to a tropical sun, or to tropical downpours, or from invasion of weeds, shrubs, bamboos, etc., this method is practically the only high-forest method which has been employed in the tropical forests of the Old World. In the Indian and Ceylon Government forests, for example, where the exploitable size for timber trees is usually taken at 6 or 7 ft. (180 to 210 cm.) in girth, it is calculated how many years it takes for trees of the girth class next below that size (which used to be taken at from 4 ft. 6 in. to 6 or 7 ft., or 135 to 180 or 210 cm. in girth) to reach that girth,

and during a period equivalent to that time all the exploitable trees are taken, as well as unsound and deformed trees of other girth classes. During that time, also, those of the next class will have grown to exploitable size, and provision for a young crop, by natural regeneration, will have been made by the care with which the fellings have been conducted. It is evident that, where the stock of trees of the second girth class is too scanty, it will not be possible to take all the exploitable trees, some of which must be left for a further period; also that, should these exploitable trees be found near blanks in the forest or where the felling of a large tree would lead to risk of damage owing to exposure or erosion, they should remain standing. In such places, even deformed and unsound trees are useful, and should be left.

This method is the one which is most commonly chosen for forests which are newly taken under scientific management, especially those which have suffered from uncontrolled and badly conducted operations, also in places where the demand is limited, whether as regards some of the species or as regards the crop as a whole. In exposed situations it is perhaps the only one which can be successfully adopted, and in Europe it is generally employed on wind-swept and steep slopes in mountainous countries.

Where experience is limited, as it is with tropical forests which vary so enormously, and few of which have been under scientific treatment for a long period, and most of which have only a small percentage of their produce marketable, it is difficult to say what other method of treatment might be substituted for the selection method under improved conditions of demand and of supervision. Clear-fellings will probably be generally unsuitable to the Tropics, owing to risks due to the sudden exposure of the soil; and, among the uniform methods, it will probably be found that the group method will be the one that most naturally adapts itself to a forest which has been treated by the

selection method, as it is really an enlargement of the same method. In a mixed forest it will probably be the most suitable, as the regeneration can be started at various points according to the requirements of the component species. In hilly countries the strip method may give better results if carefully conducted, and the compartment method might be employed with success with pure forests of light-demanding species.

A thorough knowledge of the species and their individual requirements, of the locality and climate, of the capabilities of the forest staff, and of the laws of supply and demand, is required before any particular method of high-forest treatment is finally adopted; and, until then, the selection method will be found to be the safest.

In comparison with the system of coppice the high-forest treatment fulfils other objects. It is more generally devoted to the production of large timber, while the coppice treatment is intended to supply, in as short a time as possible, small wood such as is required for firewood, the manufacture of charcoal, etc. It is true that coppice under standards combines both objects, but it rarely produces as fine timber as that obtained from high forest, because the surrounding trees are felled several times during the life of the standards, which thus rarely attain the same length of bole as trees in high forest, and the repeated exposure of the boles to direct sunlight leads to the production of much more uneven grain in the timber. At the same time, the repeated exposure of the soil by successive coppice-fellings leads to a deterioration of the soil which may be temporary only, but which, nevertheless, has some effect on the vigour of the trees.

CHAPTER IX

ARTIFICIAL REGENERATION SUBSTITUTED FOR OR COMBINED WITH NATURAL REGENERATION

It has already been stated that artificial regeneration may be employed not only to create forest crops in areas which have been hitherto without trees over them, but also to assist the natural regeneration of already existing forests or even to replace it.

Artificial regeneration has, namely, the following advantages :—

It allows a greater choice of species to be propagated, while natural regeneration depends on seed from trees in or near the area to be reafforested; it is usually effected much quicker than natural regeneration; it provides much better for the exact proportion of different species in a mixed crop, and more easily provides for giving a start to those species which require it; it can be carried on in the open as well as under shelter wood; and it is not dependent on good seed years, as, even where seed cannot be stored for more than one season, seedlings can be raised in a nursery. A greater regularity in the progress of regeneration, therefore, is obtained in this manner.

On the other hand, artificial regeneration is more costly than natural regeneration, and, at any rate as regards planting of slow-growing species, the number of plants per unit of area being smaller, their stems do not grow as straight unless the planting is very close, and therefore expensive.

Artificial regeneration can make possible the employment of the methods of clear-fellings, which are otherwise not often possible with only natural regeneration to depend on. Whether direct sowing or planting would be resorted to would depend on circumstances; but, more generally in the Tropics, the area would be planted over, as, in this manner, the soil would be covered quicker and there would be less danger from deterioration of the soil and from invasion of weeds. In poor soils and in exposed situations this method of clear-fellings, followed by artificial regeneration, would be too risky to be employed, and the same may be said of places which are quickly covered by a network of creepers, not only woody but herbaceous, such as several of the Cucurbitaceae, Convolvulaceae, etc., which quickly ascend into, bend, and stifle the young trees, and the keeping down of which would be an endless trouble and expense.

Where this operation is permitted, the necessary mixture of species can be given, either by sowing or by planting; as regards the former, either by thoroughly mixing the seeds beforehand if they are more or less of the same size, or by sowing them in different rows if they vary in size. A start may be given to any individual species by sowing it first, and sometimes by giving the seed a special preparation. In planting, the exact mixture required is even more easily given, and a start to any species can be given either by planting it first or by putting in stronger transplants of that species.

In most forests will be found blanks which are too large to be naturally regenerated, *pari passu*, with the rest of the forest. In these, artificial regeneration has to be employed in order to effect this.

Artificial regeneration is also employed to assist natural regeneration fellings where the result is a patchy or irregular crop of seedlings, or where a new species has to be introduced, or where special encouragement is required for one of the species which may be represented among the seed-bearers but not abundantly, or

which does not seed as freely or not at the same time as the others, or which does not germinate so readily, or, again, such as do germinate readily but are easily crowded out in their infancy by other seedlings.

Here, again, it is difficult to state definitely whether

FIG. 76.—Teak planted in cleared lines, Ceylon.

sowing or planting must be resorted to; but, generally, where the natural regeneration is backward in certain places only, or where it is necessary to bring in other species where regeneration already exists, planting is preferable. On the other hand, the dibbling in of seed may suffice before the natural regeneration begins to appear, or where advance-growth is desirable. In the

teak forests of Burma, for example, which are worked on the selection method, the dibbling in of teak seed is strongly advocated; but where the mixture of teak in the upper tier is scanty, temporary cultivation is permitted in many places with a proviso that the cultivators sow teak or some other prescribed seed with their crops. After an interval of some years of cultivation, the area is again taken over by the Forest Department with a young crop of teak or *Acacia Catechu* as the case may be. Fig. 76 shows a case of teak being introduced in cleared lines in a Ceylon forest.

In simple coppice and coppice under standards it may happen that the stools become too unhealthy to bear vigorous shoots, or that they may die. Although I do not know of any case in the Tropics where these have had to be renewed by putting in plants, this procedure is not unfrequent in European forests where strong plants are put in, capable of being able to maintain themselves in the midst of coppice-shoots. Plants may also be put in to be ultimately reserved as standards.

The employment of artificial regeneration, either as a substitute for or in conjunction with natural regeneration, will naturally depend on the time which the forester has for obtaining complete regeneration on the species which already exist in the standing crop, on the funds and labour which he has at his disposal, on the demand for certain species, and on the capability of supplying it with or without artificial aid. With the large areas in the Tropics, which are in urgent need of scientific management, the amount of assistance given hitherto to natural regeneration by means of sowing and planting has been necessarily small. Other measures, which are even more necessary and urgent, have taken up most of the time and available funds at the disposal of the forest officer.

PART III

TRAINING AND IMPROVEMENT OF FOREST CROPS

CHAPTER I

THE STRUGGLE FOR EXISTENCE

When a seedling has germinated, it proceeds to push the radicle into the ground, and this becomes the taproot of the plant, while the plumule, which lengthens itself above the ground becomes its stem. Both the stem and the root continue to lengthen for some time without branching—I am dealing mainly with dicotyledonous plants—but ultimately branchlets and rootlets are given forth from the main axis. If the seedling stands in an isolated position its various members will lengthen and give out more branches, and the development of the latter may even be so great as to be equal to or greater than that of the main axis. Isolated trees have comparatively large crowns and short boles, and it may even happen that side branches persist on the stem at a distance of only a few feet above the ground level.

When the seedling is only one of many of the *same age*, the lateral development goes on till the branches and roots meet those of the other seedlings, and from that moment a struggle begins between the various individuals of the seedling crop for mastery of air and light above ground and for the possession of the soil.

If the seedlings are not only of the *same age but also of the same species* the struggle is the most even of all; but ultimately some of the individuals are left behind in the race, their crowns get compressed by those of their stronger neighbours, and only the tips are able to get direct sunlight and to assimilate food, and eventually

the neighbouring crowns close over them, they pass from the dominated to the suppressed stage, and sooner or later, according to whether they belong to shade-enduring species or not, they cease to be capable of assimilating food and they die, leaving their betters to fight it out among themselves as to which will ultimately remain victors. A variety of causes may lead to the victory or defeat of the individuals composing the crop. Just as among men and other animals some have a greater inherent strength than others, among the plants some are stronger than others; and there may be other factors which may also incline the balance in favour of one or the other, such as variations in the quality of the soil, or attacks by insect or vegetable enemies, such as plant parasites, climbers, etc.

With *coppice-shoots* of the same age and species there is a similar struggle, only it usually starts earlier, for coppice-shoots at first usually grow quicker than seedlings, and when the crop consists partly of coppice-shoots and partly of seedlings, if the latter are not shade-enduring they will soon be passed and killed by the former in the struggle for light and air.

The conditions in a crop composed of coppice-shoots and of seedlings of the same age are somewhat similar to those which exist in a crop of seedlings, or of seedlings and coppice-shoots of the *same age but of different species.*

Here the struggle for existence may become very complicated. Not only do the individuals of each species vary among themselves in their rate of upward growth, but there may be a still greater variation in the rates of growth between the component species. Again, among the slower growing, there may be some which are very shade-enduring, and which may ultimately win their way into the upper tier, while among those which started well in the race there may be some which do not grow of a great size, or which are not long lived; or it may be that parasites, climbers, or atmospheric conditions may cripple some more than others. It is thus difficult to

describe the constant changes which may take place in such a crop during the various phases of its existence.

In a crop composed of *individuals of the same species but of various ages* a certain number of individuals have already established themselves in a dominant position; the struggle will then go on between those which are striving to fill up the gaps in the upper tier left between these, or in the fresh gaps which may be formed by the removal of some of the dominant trees.

In a *mixed forest of varied ages* the struggle is again more complicated by the varied requirements, rates of growth, and vitality of the various species. In one place there may be shade-avoiding trees in the upper tier with shade-enduring trees below them gradually working up their way, or if the converse is the case the shade-avoiding trees are suppressed and gradually killed. In a gap formed by the removal of one of the trees in the upper tier may be found, struggling up to the light, species which like side shelter but must have light overhead. In fact, the composition of the crop in its species, height, and girth classes and its density may vary so much from one place to another that a connected description becomes difficult.

It is evident that if this struggle for existence is allowed to go on unchecked the forest becomes largely composed of dominated, suppressed, and dying trees, and that even the stronger trees are not able to attain the same development in such a crowded wood as if they had more growing room. It is then that the forester must come in, and by special operations favour the growth of such trees as will be most useful for the owner of the crop. If the forest is a pure one the operations must simply tend to give sufficient growing room to the strongest and finest individuals, to enable them to attain the best dimensions possible for the purposes of the forest owner. In a mixed forest the strongest may not necessarily be the most valuable, and in that case the operations must aim at giving sufficient growing room to a proper proportion of the more valuable species.

The operations which are thus carried out for regulating the struggle for existence are comprised under the heads of "Cleanings" and "Thinnings"; but it will be also necessary to describe another kind of fellings to which, in India, the name of "Improvement-fellings" has been given, and which have for object the first treatment of forest crops which have suffered from want of scientific treatment, fires, grazing, etc., in order to lead them back into a more healthy condition. A few words will also be necessary on the subject of "pruning" of branches.

CHAPTER II

CLEANINGS

CLEANINGS have for object the timely removal of such constituents of a young crop as threaten to retard or suppress those which have a greater potential value.

In a pure crop, for example, those which may be removed may be stool-shoots, when there is already a sufficiency of seedlings, or such individuals as may be deformed, unsound, or attacked by parasites, or which have twisted fibre, and also climbing plants which establish themselves over the young crop, suppress it, and bend it down. In a mixed crop those mentioned above may also be removed, but, at the same time, the quicker-growing species may not be the most valuable, and may threaten the future of the latter. In this case a sufficient number of the dominant inferior species may be cut back or lopped, in order to foster a proper proportion of the valuable ones. It may even happen that the inferior species has already grown into a full-sized tree, while the more valuable one may yet be in the seedling or sapling stage, and that it is desirable to sacrifice the tree for the sake of the smaller individual. In the Himalayas, for example, it is, or was, no uncommon sight to see a gigantic spruce fir having no local value girdled in order to make room for a sapling of deodar cedar.

The *cutting back of climbers* is a very necessary operation in a great many tropical forests. There are certain climbers, the value of which is such that it exceeds that of the trees up which they climb, and which

they overtop, as *e.g.* rubber vines, such as certain species of *Landolphia* or *Clitandra*, or certain kinds of canes such as *Calamus*. Such climbers are necessarily left untouched, or they are trained in such a manner as to give the best return possible; others, which are of relatively small value, should be grubbed out, if possible, or if the area to be covered is too large to permit such thorough extirpation, they should be cut back, the stool being shattered by blows of the axe, first with the edge and then with the back, if it is of sufficient size to be able to be dealt with in this manner. It is also advisable to cut the climber a second time as high up as the arm will reach, as otherwise any shoots given out by the stool will soon obtain a support by means of which they will draw themselves up the tree once more.

Certain herbaceous or semi-herbaceous climbers will do a lot of damage to the young crop, and even to larger trees, by covering their crowns as with a web. Such are numerous species of Convolvulaceae, particularly of *Ipomaea* and *Merremia*, many Cucurbitaceae, such as *Cucumis*, *Momordica*, *Luffa*, *Adenopus*, etc., and representatives of several other natural orders, such as Leguminosae, Rubiaceae, Asclepiadeae, Acanthaceae, Ampelideae, and others. Such climbers should be pulled up, or if too strong they should be stubbed out. Where the climbers have a certain commercial value, as *e.g.* for their fibre, the operation may be farmed out under supervision and may even become remunerative.

Of *parasites*, those belonging to the natural order of the Loranthaceae, such as *Viscum* and *Loranthus*, are the most abundant. In the mountains of southern India and Ceylon a large number of introduced Australian wattles, especially *Acacia Melanoxylon*, have been killed by *Loranthus*. If such are found on small trees they should be cut out, and it may even be necessary to cut down entire trees whose crowns have been invaded by them in order that they may not become centres of distribution.

When cleanings have to be executed within a crop

consisting entirely of young individuals, those which are hurtful can be made to allow growing room to the more valuable ones by *topping* them, that is, by cutting off their crowns to below the level of the crown of the young trees which it is desired to help up. It may suffice to prune some of the branches from the dominant tree and thus give the necessary amount of growing

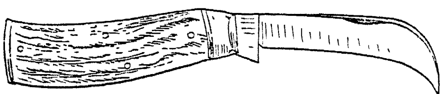


FIG. 77.

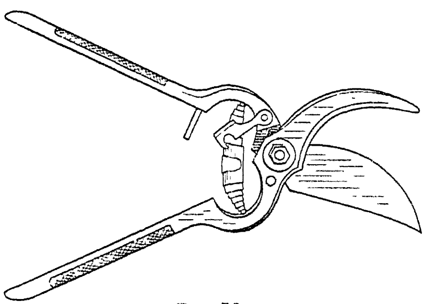


FIG. 78.

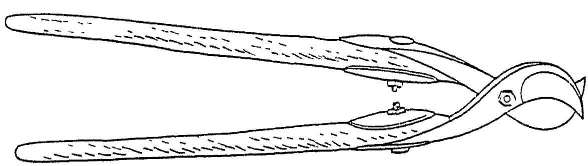


FIG. 79.

room. The implements which can be used for small wood are either the pruning-knife (Fig. 77) or the secateur (Fig. 78), or indeed any sharp knife, while for stronger wood a heavier slashing knife or bill-hook is required. Pruning-shears (Fig. 79) are also powerful, and useful for pruning branches which are not too far overhead. For branches which are some distance above the ground the pruning-hook (Fig. 16) or the tree-pruner (Fig. 17) will have to be employed, or if the

branches are too stout for these pruning-saws (Figs. 80 to 82) will have to be used. When trees have to be removed they can be felled by felling-axe or saw, or by the two combined, or if they have no marketable value they can be *girdled*, unless they belong to those species which are not killed by girdling. In girdling a tree care should be taken to thoroughly clear the bark down to the cambium, and to let no strands of bark or bast remain to join the upper and lower lips of the wound.

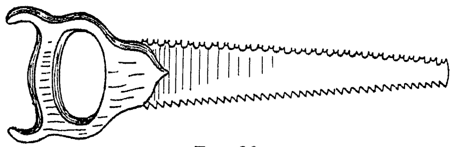


FIG. 80.

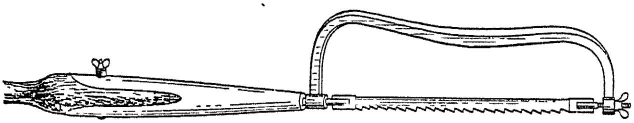


FIG. 81.

FIG. 82.

This is particularly liable to happen with trees which have grooves running down their boles. Unless the bark is thoroughly cleared, the strands of bast left may be sufficient to preserve the life of the tree. When removing whole trees over seedlings of valuable species, great care should be exercised, especially where fast-growing brushwood is liable to spring up, not to carry out this operation with too heavy a hand. I have seen a wood in the Himalayas where girdling, which was to foster the growth of young deodar cedar, only led to the whole area being overrun with brambles. Wholesale

girdling has also the drawback of attracting innumerable insects and fungi which are hurtful to forest growth. In such places the operation should be carried out lightly, but at repeated intervals. A frequent repetition of the operation is also required in such crops as are in the fullest vigour of upward growth, and where, consequently, the quicker-growing species quickly fill in all the gaps and exclude light and air from the slower ones.

The forest guards of the beat should be taught how to carry out simple cleanings. They should be supplied with light axes and with knives, with which not only overhanging branches or saplings of inferior species can be cut back, but also any creepers which they may pass during their daily inspections. In some localities this will not be sufficient, and the areas will then have to be gone over under the direction of a responsible officer.

Cleanings should be begun as early as possible when regeneration fellings, according to one of the uniform methods, are made; it may be necessary to start the cleanings before the after-fellings shall have been completed. In forests worked on the selection method the cleanings will largely be made over advance-growth, which must not be left under suppression for too long a time, otherwise it will be apt to assume a hide-bound, bushy appearance, and will not be likely to take a good shape even after light has been let in.

CHAPTER III

THINNINGS AND PRUNING

It has been indicated in the chapter on "Struggle for Existence" that in the early stages of a forest crop the young plants, whether seedlings, coppice-shoots, or root-suckers, first send leading shoots, then develop branches and form crowns, which expand as the young tree grows in height, until they meet the crowns of their neighbours. The component young trees of the crop then begin to struggle among themselves for room to develop, while they race up to the light, and soon they resolve themselves into dominant, dominated, and suppressed, to which, in time, may be added the dead. Thus there are at first a great many more stems on a given area than will ultimately be the case when the crop becomes exploitable. But if those which ultimately have won the victory are permitted to work their own salvation, they do it at the sacrifice of their own vitality and strength; the trees are apt to grow lanky, with compressed crowns, and they will not have attained the same dimensions as they would have done had those been got rid of earlier which they gradually mastered. The dominated and suppressed trees themselves were precluded from making much growth, but by their presence, both in the leaf-canopy and in the soil, they took up some of the precious room which was needed for the full development of the dominant trees. It is in regulating this struggle for existence, and in providing sufficient growing room for those which it is intended to retain in

the crop, that the forester comes in and carries out *thinnings*.

The most intense struggle goes on while the trees grow in height; a time comes when they have attained their maximum height, after which there is no longer a struggle for light above, but for expansion of the crown and girth development. It is then during the stage of upward growth that the young trees require the most constant attention in order that they may develop in the best manner possible.

It will depend on the object with which the crop is raised, on its nature and composition, and on the soil and locality, when these thinnings are to be started, how often they are to be repeated, and how heavy they are to be made.

Generally speaking, it may be said that while the object of the forester must be to keep the soil well protected and to keep the leaf-canopy complete, not only for its preservation, but, in forest grown for high-class timber, to produce it of as good a quality as possible, it is advantageous to start thinnings as soon as the struggle for existence begins. It may be that if this be done the cost of the operation will not be covered by any means by the money return from the sale of the produce thus obtained; but, nevertheless, the benefit done to the young crop may be sufficiently great to more than compensate for the immediate loss on the transaction. In practice the beginning of thinnings is usually delayed until the thicket has turned into young pole forest, *i.e.* until the lower branches have died down, and the boles have been sufficiently cleared to allow fairly easy access into the young crop.

The intensity of the thinnings is also regulated by the factors which have been stated above. If the object of the forester be to produce clean timber, as free of knots as possible and of even growth, and to obtain tall trees, the leaf-canopy should be interrupted as little as possible, at any rate during the period of upward growth. During this period the lower branches die down, while

the crown lengthens upwards, the sunlit portion of the crown being only capable of assimilating food for the branches down to a certain depth; the branches not so nourished die down and drop off before they have attained sufficient dimensions to form any material knots in the timber. If, on the other hand, direct light is let in on these lower branches, they are capable of feeding themselves, and they grow and thicken to the detriment of the quality of the timber.

If the object be to obtain a large crown and to get a material thickening of the bole as quickly as possible, the length of the bole not being of any great importance, then the crowns should be given as much room as they require for a full development. Such might be the case, *e.g.*, in a rubber plantation.

If a young crop has been planted it will usually require thinnings later and not so heavy as a crop derived either by sowing or by natural regeneration, in which the young trees will come up in places much thicker than those which have been planted. In the latter, however, the thinnings will probably be more uniform. In the same way crops on good soils can be dealt with with a heavier hand than those on poor soils, and those in dark or sheltered localities than those in exposed or well-lit situations, and shade-avoiding species than trees which are shade-enduring. There are also certain species, such as many of the Meliaceae, which, although they are shade-avoiding during the greater part of their existence, require shelter during early life. These can be dealt with lightly at first, and with more vigour later on. In fact, the execution of thinnings requires such a thorough appreciation of a large number of factors, especially in a mixed forest, that it should never be entrusted to ignorant subordinates, but only to fully competent foresters. It should always be borne in mind that although it may only take a certain number of minutes to cut a tree down, it will take as many years, or more, to grow another to replace it.

Foresters usually distinguish between three degrees of thinnings:—

In making *light* thinnings (*coupe sombre des éclaircies* of French, and *dunkle Durchforstung* of German foresters) only suppressed or dead trees are removed; in *moderate* thinnings (*coupe modérée*, or *mässige Durchforstung*) dominated, suppressed, and dead trees are cut out, and in *heavy* thinnings (*coupe claire*, or *starke Durchforstung*) some of the dominant trees are felled as well as the dominated and dead; but the suppressed trees may be taken out or left according to the necessity of giving shelter to the soil. In this operation, although the leaf-canopy should not be materially interrupted, it should be considerably lighter.

In a pure crop of uniform age the thinnings will at first be light, and even these must be done very cautiously at first in a dense crop, the stems of which are thin and lanky, and incapable of standing upright unless supported. In the Tropics generally, where the sunlight is very intense, it will be best to make all the first thinnings light and to repeat them as often as possible. When the remaining stems are strong enough to do without support the thinnings can be made moderate, and when the trees have reached their full height it will be possible to favour the strongest among the dominant trees by the removal of the more weakly, unsound, and crooked ones; while the time comes when even among strong and healthy trees some must go, in order to let the remainder attain their full development. In doing so the crowns are slightly isolated, but a certain number of suppressed trees are allowed to stand, or an underwood is raised, which will shelter not only the soil but also the boles of the trees from direct sunlight. Ultimately these thinnings merge into preparatory-fellings. Heyer[1] illustrates the operations carried out during the rotation of a crop worked according to one of the uniform methods in the manner indicated in Fig. 83. The circle ABCDE represents the rotation of the crop, the

[1] Heyer, *Waldbau*, p. 290.

rotation of which starts at A with the seed-fellings. During the first period of its existence (A to B) the after-fellings are being made, while during the next (B to C) the area is gone over with cleanings. Next come repeated thinnings during the periods C to D, D to D_1, D_1 to D_2, and so on to E, at first at short intervals, then more protracted, until, during the last period of the rotation (E to A), the preparatory-fellings are carried out.

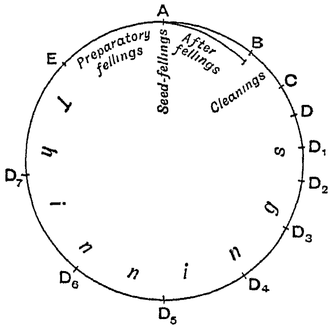


FIG. 83.

In a mixed crop the different species may be found in groups, in which case each separate group may be treated like a pure crop; or, as is more usually the case, the mixture may exist, probably in varying proportions, all over the area to be treated. In this case the care of the forester must be devoted to encourage a proper and sufficient proportion of the more valuable species, and thus it will not necessarily be the strongest individuals that will be helped along, but, where inferior species tend to crowd out the more valuable ones, they will have to make way for them until the proper proportion of different species has been obtained. If the valuable species are the faster growing, and are shade-avoiding, they will soon form an upper tier or story, the other species protecting their boles and the soil below their open crowns. Thus, to take an example from Ceylon forests, under an upper tier of *Mimusops hexandra* and satinwood (*Chloroxylon Swietenia*) will be found a lower one of shade-enduring species such as *Nephelium Longana, Sapindus emarginata, Hemicyclia sepiaria*; while ebony (*Diospyros Ebenum*), which is also shade-enduring, will work its way into the upper tier, but more slowly. It will thus frequently happen that, in a mixed crop, after the full growth in height of the

principal species has been attained, the crop resolves itself into a storied forest, the upper story of which is pure or nearly so, and composed of the crowns of the principal with some auxiliary species, while the accessory species form one or more stories below them. It is evident, however, that, in order to bring the principal species into the upper tiers, the leaf-canopy has to be opened out sufficiently, and that this may lead to the deterioration of the soil unless the operation is most carefully conducted. Although in Europe the isolation of certain selected trees, for the production of large timber, is sometimes begun early, this is not to be recommended as a rule in tropical forests, where the intensity of the sun's rays and the scorching power of the hot winds are much greater, and where not only the isolated trees are liable to deteriorate, but the soil is likely to be invaded by weeds and creepers of all sorts.

In a crowded wood composed entirely, or nearly so, of coppice-shoots, it may become necessary to make at least one thinning, in order to give the strongest shoots more room. This will not be necessary, however, in coppice worked on a very short rotation, which is only intended to give wood of very small dimensions. But with the coppice-crops intended to give cord-wood, mine-props, etc., it has been found that by cutting out the weaker stool-shoots the remaining stems benefit materially and give a better out-turn at the time of exploitation. In a coppice under standard thinnings are necessary (as well as cleanings) in order to free such seedling growth as is intended to develop into standards. This is all the more necessary because, at the outset, the growth of coppice-shoots is much quicker than that of seedlings.

In a forest composed of trees of different ages the thinnings will have to vary in character and intensity from place to place, according to the character of the crop. They will be heavy where the trees have attained their full height, and light where they are young; a mixture will also regulate the heaviness of the thinnings according to its requirements.

While thinnings are being made, the cutting of climbers should also always be attended to, and if the trees are infested by parasites, those which are so attacked should be removed by preference, especially if they belong to inferior species.

In a forest the upper tier of which, if there are more than one, is composed entirely of crowns of trees which have attained their full height, there is no longer a fight among them for attaining the light, but for expansion of the crown. If no thinnings are done, the crowns of the weaker get gradually compressed, but this is a slow process, and in the meanwhile the production of timber per unit of area is not as great as it might be. It has been proved that by giving more growing room to a certain number of the dominant crowns the production of timber gets much increased. To what degree the thinning out may be done will no doubt largely depend on species, soil, and locality, but the opinion of European foresters seems to favour the complete isolation of the strongest or most valuable of the trees, in order that they may have plenty of room to spread out and attain an exploitable size as soon as possible. These thinnings, which have been called *Plenary thinnings*,[1] might lead to the deterioration of the soil, and where they are carried out it is necessary to provide for an underwood, either by means of species which have sprung up under shelter of the upper tier or which have been left behind in the struggle for height, or to provide one artificially by sowing or planting, preferably the latter, as it will attain the necessary dimensions earlier. As has already been seen, where the species in the upper tier are mostly shade-avoiding, a lower tier, naturally raised, is easier to obtain.

The time for marking trees for thinnings is when they are in full foliage; it is only then that the space occupied by the crowns can be fully appreciated. The best time for felling, on the other hand, is during the period of least vegetable activity. By so doing the damage done

[1] E. E. Fernandez, *Manual of Indian Sylviculture*, p. 499.

to the standing crop will be minimised, and the shock caused by partial or total isolation will also be smaller.

One of the greatest obstacles to the execution of thinnings in many tropical forests is the difficulty of obtaining a sale for the produce so obtained. In a country where most of the inhabitants live in mud huts, the roofs of which are made of thatch laid over thin sticks or bamboos, and the furniture of which is limited to the barest necessities, the local sale will also be small; and the transport of any but exceptionally fine timber to a distance may cost a great deal more than the price obtained. It is only in the neighbourhood of larger towns, or where steamers or railways, factories or mines, create a demand for smaller wood, such as posts, small beams, rafters, mine-props, and firewood, that such operations are directly remunerative. As the forester is usually expected to make the forests under his charge pay, he finds difficulty in obtaining funds for operations which, although they will be for the benefit of the forest in the long run, show an immediate deficit. In places where the produce obtained from thinnings finds an immediate sale, these not only enable the forester to give the forest-owner a constantly recurring revenue, but they increase the productiveness of timber per unit of area; that is to say, that when ultimately the regeneration fellings are made, more timber and better timber are obtained than if the forest had been left untouched while the trees grew to maturity.

The subject of *pruning* has already been touched upon in the preceding chapter with reference to cleanings. Although in tropical forests pruning is an operation which has not been paid much attention to, owing to the large number of other urgent matters which have required the attention and time of foresters, it is necessary to know how pruning should be carried out.

In a crowded wood of trees of the same age the lower branches begin to die out after leaf-canopy has been formed, and as the trees continue to lengthen

their crown the lower branches of the crown die down. The depth to which the crown remains green will depend on the species and also on the denseness of the neighbouring crowns. In many species, after the lower branches have died they drop off, breaking off close to the stem, and the wounds made are quickly occluded, the bark closing over them. In others they take long to drop off, or only portions break off, leaving snags with a rough uneven end through which fungi find an inlet into the tree and lead to unsoundness. It is always advantageous to prune such branches and all dead branches, and this should be done close to the stem, care being taken not to injure the bark of the tree.

Green branches are also pruned sometimes in order to lengthen the bole; the operation at the same time leading to the formation of more cylindrical timber. This might be done, for example, in trees which are isolated and whose lower branches have not died down, or where there are trees of different ages, if some are exposed to direct sunlight on one side on which their lower branches have not died down. This is, however, an operation which should only be made with care. As cracks are liable to appear on the exposed surface, they offer a ready access to fungoid diseases. As a rule, therefore, large branches should not be lopped. The size up to which they may be lopped will vary according to the quickness with which the wound can be occluded. Schlich[1] states that it is dangerous and objectionable to prune branches of a diameter greater than 3 inches (7·5 cm.).

When trees which have been growing under complete leaf-canopy are suddenly isolated, as *e.g.* when after-fellings are being made, their boles, on being exposed to direct sunlight, give out a number of shoots, known as *epicorms* or as *epicormic branches.* These, if they are allowed to remain, will divert the sap from the crown and will cause its branches to die from the top; the tree will become "stag-headed." It is

[1] *Manual of Forestry*, vol. ii. p. 285.

therefore necessary to prune the epicorms, and the operation may have to be repeated once or even twice.

The pruning of live branches during the growing season is more dangerous to the tree, and should be restricted to the period of greatest rest. Wounds of any size should be painted over with coal-tar or coal-tar and turpentine, in order to prevent the ingress of fungi. The implements which are used for pruning have already been described in the last chapter. Saws leave a rougher surface than cutting implements, but with the larger branches they can really make a straighter cut, and they are not so liable to injure the adjoining bark. For pruning at a height above the ground saws or other implements fixed at the end of a pole may be used, but if the height be above 3 or 4 metres (10 to 12 ft.) a sufficient accuracy cannot be obtained, and the process is also very tiring to the workman. Light ladders should therefore be employed, and climbing irons, which injure the trees, should be prohibited.

In pruning a branch it should be taken off as close to the stem as possible without injuring the bark. If the cut is given with a knife, a sharp upward cut is the best, and for heavier branches cut with a bill-hook or pruning-hook a cut is first given above to prevent the bark tearing, and then a blow given upwards from below. With a pruning-saw the same order would be the best, but as the weight of the branch, as it gradually bends down during the operation, pinches the saw and prevents it being worked to and fro, it is best to give the first portion of the cut below and to finish off from above. If the branch is heavy it is necessary to cut it first at some distance from the stem, and when this is done to cut the stump off close to the stem. Unless this is done the branch will split and some bark will be torn off.

CHAPTER IV

IMPROVEMENT-FELLINGS

THE name of "Improvement-fellings" has been devised by foresters in India for the operations which are carried out in the ruined or badly damaged forests in order to lead them back into a more healthy condition, and to enable them to be worked on proper sylvicultural lines.

It is the case, unfortunately, that a very large proportion of the tropical forests, when they are taken under forest management, show signs of having suffered from one cause or another, and that it is difficult to apply to them any of the recognised sylvicultural systems. The causes of this deterioration are various; the principal ones probably are fires, shifting cultivation, grazing, and unrestricted fellings. In countries which are so subject to sudden climatic changes as are those under the Tropics there are a number of other factors, such as cyclones or tornadoes, floods, extreme drought, and even, in the highlands, frosts, which contribute largely to the damage done.

The result is that when a forest is taken under forest management its crop is most irregular, the trees too dense here and too thin there, valuable species dominated or suppressed by inferior species or by unsound trees, the poles and saplings misshapen and unsound from results of fires and grazing, the leaf-canopy interrupted by frequent glades or blanks, and the soil exposed or hardened by the tramp of cattle.

In such conditions it is impossible to apply any of

the sylvicultural systems to the forest; it has first to be restored to a condition in which one or other of these systems may be employed for working and regenerating the forest, and this restoration is effected by means of improvement-fellings. It is for this reason that in India by far the greater part of "Working Plans," or schemes for working the forests, prescribe improvement-fellings.

It then remains to be seen what is meant by improvement-fellings. Originally the term was taken to mean the same as the *coupes d'amélioration* of the French foresters, among whom most of the officers of Indian forest service had been trained. These *coupes d'amélioration* included such operations as cleanings, thinnings, and the weeding out of unsound trees, and some foresters still give this restricted meaning to improvement-fellings. But, with others, this meaning has come to be considered not to be broad enough.

First of all, among the growing crop of saplings and poles there are many which are gnarled, crooked, or unsound as a result of grazing or forest fires. These would never develop into good trees, and they are still young enough to give vigorous stool-shoots capable of growing to useful dimensions, and to give better timber than the misshapen trees which they replace. Where, therefore, there is not a sufficient and healthy advance-growth or sufficient cover overhead, it is to the advantage of the forest to coppice these. This brings coppicing into the operations which are included in improvement-fellings. Among the larger trees there may be some which have reached or even passed the exploitable size, and which would deteriorate if kept in the crop until the time when it is to be brought into working under one of the recognised sylvicultural systems. If their presence can be spared, *i.e.* if they are not wanted as seed-bearers, or to cover the ground, or for other reasons, it is to the advantage of the forest and of its owner that they should be removed. On the other hand, it may be desirable or even absolutely

necessary to keep some unsound or badly shaped trees where there is nothing better to cover the ground or to bear seed. It is also a fact, to which many foresters find it hard to be reconciled, that the owner of the forest expects to realise immediate revenue from his forests, and that operations which are likely to bring a return in the dim and distant future, however excellent they may be, are not easy to support; that, in fact, funds for carrying costly operations which bring no immediate return are not easy to obtain. The improvement-fellings then resolve themselves into a very miscellaneous operation. Fernandez[1] thus describes an improvement-felling:—

"It is thus evident that an improvement-felling is not an elementary operation of a special kind, but is essentially a composite one, combining in itself the attributes and objects of every kind of felling already treated of. At points where utilisable advance-growth exists, it will assume the character of an after-felling or of a jardinage cutting. Where the crop is too dense, it will become a preparatory-felling, or a thinning or a cleaning according to the age of the component individuals. In other places it may partake of the nature of a seed-felling. Where frost and other dangerous atmospheric influences are not to be feared and the soil cannot suffer from exposure, there a more or less large clearing may be made, if the whole of the standing stock is unsound or deteriorating and early regeneration is certain. In such places the younger individuals capable of throwing up good coppice-shoots should be carefully cut back. Young damaged stems of valuable species should also be cut back, where the regrowth from them would improve the constitution of the crop. In frosty localities, where the forest is open, it is useless to attempt any cutting back, as the new shoots are bound to get frost-bitten in their turn and in the end prove no better than the original individuals. In such places the only resource left is to allow the

[1] *Op. cit.* p. 509.

standing stock to gradually make its way up and ultimately form sufficient cover and shelter for new reproduction from seed. Crowded advance-growth may have to be cut back or thinned out. In all this varied work, while clearing the forest of all unsound, unhealthy, and deteriorating or harmful stuff, the main thing to aim at is to get the ground covered with sound, valuable, and growing material as quickly as circumstances in each case will allow. Moreover, in mixed forest, a proper distribution of the component species should not be lost sight of."

The above description is so complete that there is little to add to it. As I have already pointed out, the removal of unsound and deteriorating trees can only be done where there is something better to take their place. As a rule, they should not be removed from the edges of blanks or where the ground would be too much laid bare, nor from the edges of ravines or high banks of streams, where the felling might lead to erosion.

A point which has also not to be lost sight of is what treatment it will be desired to give to the forest once the improvement-fellings have been completed. According to the method of treatment which should be applied ultimately, the operations should be so carried out as to lead the crop to the condition which will make it possible for that method to be adopted. If, for example, it is considered that the selection (jardinage) method will be the one most suitable to the crop with respect to the requirements of the forest-owner, the improvement-fellings should not only aim at having the proportion of species according to their value, but also the proper proportion of age or diameter classes. This will not be effected in one operation, but may take up a large portion of the rotation of the principal species, and will be obtained by weeding out those that are superfluous in each class, and in fostering those which are badly represented by helping those of a lower class to fill in vacancies. If the group method is considered to be the most suitable, the efforts of the forester must be

devoted to the formation of suitable groups in each of which uniform fellings may be made possible, and so on. The introduction of the compartment method will in most cases be the most lengthy, owing to the difficulty of leading the crop to a sufficient homogeneity for its requirements. It would, however, be more quickly attained with a pure crop, especially if the majority of the crop is more or less of the same age.

But before the improvement-fellings are started it will be necessary to protect the forest from fire. There are, in the wet zone of the Tropics, forests which are naturally fire-protected, and even in the moist zone there may be some which are safe; but elsewhere it is necessary to introduce fire-protection in order to improve the soil, by getting it permanently covered with vegetation, fallen leaves, or humus, and to enable the seedlings, which have been killed down to the ground by repeated fires, in making a start. It may happen that, later on, there may be an intermittence of fire-protection under special circumstances, such as when an invasion of bamboos prevents natural reproduction; but as far as our present knowledge goes the necessity of safety from fire, before making improvement-fellings, is imperative.

Grazing should be excluded from all portions under improvement-fellings. This is necessary not only to improve the soil, but to save young seedlings, saplings, and stool-shoots; and lastly, fully a year before the fellings are begun, climber cutting should be carried out. It would be even better to carry out this operation two years ahead, as it will allow the dead climbers to decay. Thus, not only will the crowns be free and it can be more easily seen what is to come out, but, when felling the trees, the stems of the climbers will no longer be strong enough to drag other trees down together with those which are felled. Large climbers pass from the crown of one tree into that of another and bind them together. They often have very great tensile strength, and, unless their fibres are decayed, the fall of one tree may lead to the crown of the next one being broken and

pulled down, and the fall of this in turn will cause damage to the crowns of other trees beyond, which are also held by the strands of the same climber. It is also impossible to guide a felled tree in its fall so as to do little injury to the standing stock if it is held back or diverted by strands of climbers.

It is evident that improvement-fellings are very delicate operations, which must vary in their nature from place to place according to the requirements of the crop. It is therefore essential that they be carried out by skilled foresters. It is impossible to carry them out by rule of thumb, and subordinates cannot be put in charge of them. The only operation which can be carried out under the supervision of a subordinate is climber-cutting. If there are epiphytic trees, like several species of *Ficus*, which threaten to constrict valuable trees, they may be treated like climbers and cut through; but all other work should be carefully supervised, even down to the removal of unsound, crooked, and inferior trees, as there may be special reasons for preserving them.

PART IV

SPECIAL MEASURES OF MAINTENANCE AND PROTECTION

CHAPTER I

DEMARCATION

Although demarcation is in itself not a sylvicultural operation it is one which is necessary to enable the forester to work his forests systematically, without fear of encroachments and, when legally protected, of trespass. In a forest which is not demarcated the forester is helpless against encroachments, cattle trespass, and illicit fellings; he cannot obtain legal redress, as he either cannot prove the offence, or, if he can, he cannot prove that the offender was aware of his trespass.

In this chapter it is presupposed that the title-deeds to the forest have been obtained and its boundaries actually defined thereon, and that there will be no opposition to these being patently and permanently fixed on the ground by demarcation.

The nature of the boundaries will vary according to the configuration of the ground, the nature of the forest, and the character of the adjoining lands.

The best and most permanent boundary line, where it can be obtained, is the crest of a ridge or of a spur, or, in other words, a well-marked watershed. Such a boundary needs little artificial addition except the erection of boundary pillars at the points where it joins or leaves the watershed, and, from distance to distance, on salient points along the ridge. Next best to a ridge comes a watercourse. A large river is the best, but any well-defined watercourse will be a good boundary line. It is true that the course of

the river or stream may change, in which case the boundary line may also have to be altered in accordance with the laws of the land in force for the time being; but unless the change of bed is considerable it will not materially affect the boundary, and all that may be necessary is to place boundary pillars at prominent points, usually at bends in the stream, in places least liable to erosion, *i.e.* on the concave side of a curve where the current is least strong.

After these natural boundaries, where they are available, existing roads make excellent boundary lines, but, as the traffic along them is greater, it is necessary to put up boundary pillars or other boundary marks not too far apart; they should be sufficiently near to each other to enable anybody to see from one to the next.

Elsewhere, the boundary line has to be cleared and its angles indicated by boundary posts or pillars, other pillars or other marks being put up from distance to distance as may be required.

The most common form of artificial boundary for a forest is a cleared line of a width which may vary according to the nature of the forest or of its liability to forest offences, or according to whether fire protection has to be carried out. In the last case the boundary line may have to be made very wide, as it will be at the same time a fire-line. In a forest where the lines quickly close, owing to the crowns of trees meeting overhead or strong undergrowth or regrowth springing up in them, especially when the lines have forests on either side, it is best to make the boundaries wide, *i.e.* 5 to 6 metres wide (15 to 20 feet); but if cultivation or cleared land adjoins the forest and there is no danger from fire, or if the nature of the undergrowth is such that it will not quickly obliterate the line, it may be sufficient to make it, say, 2 metres (6 feet) wide, unless the forest is liable to suffer from illicit trespass. Where the forest is liable to such attacks the line should be made wide enough for an inspecting officer or forest guard, on his beat, to be able to see anybody, or any cattle, crossing

the line from a long way off. For reasons of easy inspection, therefore, as well as for reasons of economy in demarcation, boundary lines should be made as straight as practicable, with as few angles as possible. An irregular boundary, with many projecting and re-entering angles, is not only much more expensive in itself per unit of area that it protects, but is made still more so by the number of boundary pillars which have to be erected at the angles. If, therefore, a forest with irregular boundaries has to be demarcated, it is to the interest of the owner of the forest to negotiate with the

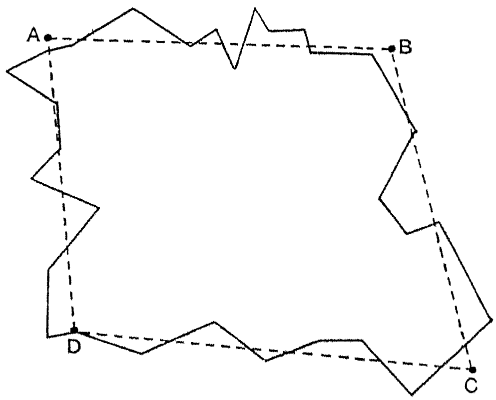


FIG. 84.

adjacent owners for an exchange of his land with some of theirs in order to rectify his boundaries, and it may pay him well to give in exchange a considerably larger area than that which he receives in exchange. Fig. 84 shows at a glance how, without materially affecting the area, the irregular boundaries of a piece of forest can be straightened along the lines AB, BC, CD, and DA, thus effecting a saving in the length of lines to be cut, the number of boundary pillars to be erected, and in subsequent cost of upkeep.

In places where, notwithstanding careful clearing, boundary lines are apt to get thickly overgrown during a year, it will probably be cheaper, and certainly more advantageous, to replace the cleared line by a ditch,

unless fire protection has to be carried out. Such places occur in the wet zone; in the wet low country of Ceylon, for example, such a system of demarcation has been found most effective. These boundary trenches should be made sufficiently deep and wide to be easily recognisable, and in loose, friable soil, where they are apt to be easily silted up, they should be deeper and wider. In the hard laterite soil of Ceylon they were made 18 inches (45 cm.) deep and of the same width, but on softer soils something deeper is required, with the sides sloping more according to its looseness. If these trenches are not intended to act as drains they should not be made continuous, but should be interrupted from distance to distance, the lengths of the trenches depending on the gradient and on the nature of the soil. The spoil earth from the trenches should be heaped up on the forest side of the trench and a little away from it in order that the earth may not be washed back into it by the first rains. This spoil earth will make an embankment which will make the boundary more noticeable. A narrow boundary line of this nature requires more frequent boundary marks than one which is better defined on the ground.

It is always desirable to have an inspection path made on the line or, if there is a trench, on the forest side of the trench. If wheeled traffic has to pass along this line, the inspection path may be replaced by a cart-road, which should not be less than 4 to 5 metres (12 to 16 ft.) wide, or more if the traffic is likely to be heavy. An inspection path which is to serve only for foot or mounted traffic may be made 2 metres (6 ft.) wide.[1] In making it, especially if it is to be used as a bridle-path, all protruding roots or stones should be dug out, and if there are any hollow places, such as would be made by termites' nests, under the surface of the soil, they should be filled up and stamped down. In very steep places and in meeting large obstacles it may be

[1] If the inspection is to be made on camels or elephants the path should be made wider, especially if the forest be thorny.

necessary to divert the path a short way from the boundary.

Boundary pillars should be erected at all angles of the line, and if a straight line be long, intermediate ones may have to be erected from distance to distance. All pillars should bear a serial number, the numbers starting from a well-known point and running right round the forest back to the starting-point. Roman numerals should be avoided, as being more costly and less well understood; but it may be necessary to mark the numbers in the vernacular character of the country. These boundary pillars may either be monoliths or they may be made of stone or brick masonry, or they may consist of cairns or of cones of earth with a solid timber post which has been driven into the earth sticking out of the middle. Stone monoliths are so fashioned that, although the portion which remains above ground is cut into rectangular, prismatic, or cylindrical form, that which is buried below the ground is left rough so as to get a better grip and to be less easily uprooted (Fig. 85). These boundary marks, although they are fairly portable and can thus be fashioned in one place and easily distributed even with mule or donkey transport, are not to be recommended for places where there is a heavy traffic, as careless carters frequently knock them out of the ground or break them with their carts. They are also apt to be broken up by mischievous persons or put into new positions.

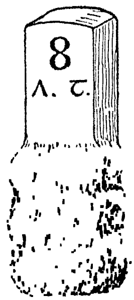


FIG. 85.

Brick or masonry pillars, with good foundations and with the number engraved on a slab of stone let in on the external face, are the best. In India it is usual to put in some charcoal under the foundations, as it is not perishable, and makes it possible to find the exact site even when the pillars have been removed. As a usual rule it will be best to paint the pillars with a coat of whitewash or with some other conspicuous colour; an

exception must be made, however, in countries inhabited by elephants. Both the Asiatic and the African elephants have an instinctive dislike of white things, and seem to find a particular pleasure in destroying them.

Where the erection of masonry pillars is difficult or too costly, cairns may be substituted for them. These should be made of as heavy stones as possible piled round a stout post of durable wood which has been driven deep into the ground (Fig. 86). On the post should be displayed the serial number of the boundary cairn; this can either be painted on a tablet which is nailed on or let into the post, as shown in the illustration,

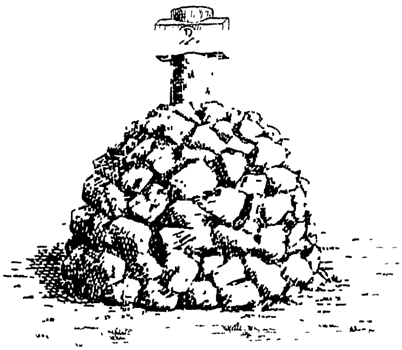


FIG. 86.

or on a prepared flat surface on the post itself. In places where there are wild elephants the tablets should not be white. As an additional protection a piece of barbed wire may be wound spirally round the post.

If stones be not available for the construction of a cairn, a mound of earth may be raised instead, the earth being well beaten down and then covered with turf to save it from erosion.

The direction of the boundary line may be indicated on the boundary marks either by a painted or cut line on the top of masonry pillars, or by a painted line down the sides of posts.

Between the boundary pillars or cairns it is usually necessary to put up other intermediate marks as a warn-

ing to trespassers. These marks may either consist of pillars of a size or shape different from that of the main boundary marks, or of tablets affixed to posts or to the trees on the boundary, on which is inscribed the nature or name of the forest, such as *e.g.* "Government Reserved Forest." Iron standards with cast-iron plates are also used sometimes, but these again are to be avoided where there are wild elephants. I have seen in India such standards twisted into weird shapes by these animals. Likewise, on a forest boundary in the Sudan, where white-painted tablets proclaimed from distance to distance that behind them stood Government Reserved Forest, I have seen about 90 per cent torn down by elephants, and many of them broken.

The planting, along the boundary lines, of trees of a special kind which can be easily recognised by their habit or by their flowers, such as *e.g.* various palms, or the flamboyant tree (*Poinciana regia*), which has showy scarlet flowers, or various species of *Ficus*, has also been proposed many a time; but I am not personally aware of any case where this proposal has been carried out. The planting of *Ficus* would lead to the danger of its seeds being carried by birds on to other trees on which they would germinate, and which they would ultimately kill by the embrace of their aerial roots.

A survey should be made of the boundaries of the forest and a map prepared showing them, and also the position of boundary marks, and of any other prominent features. At the same time a register should be kept in which the direction, length, and nature of each line should be entered, as well as the exact position of each pillar or cairn, and a description of principal features, together with their exact position with reference to the line. Such features are, for example, roads or streams crossing or running along the line, villages or houses outside the line, etc. In this register will be entered from time to time any alterations of the boundary or of the position of boundary marks which may become necessary, also a record of cost of delimitation and

upkeep. It is very desirable that this register be started as soon as the delimitation is begun, and that it be kept up to date. Any neglect of this principle will lead to further procrastination later on, when other forest works come to take up the forest officer's time.

Should any lands belonging to another owner be "enclaved" within the forest, they must also be demarcated. It is usual in this case to make the boundary pillars of such enclosures of a different size or shape from those which mark the outside of the forest.

If a forest be of such a size as to be subdivided into different blocks or compartments, these should also be indicated on the ground by means of marks. Whenever possible or practicable, natural features, roads, or bridle-paths are taken as boundaries, or it may be necessary to clear lines of demarcation through the forest. Wherever these boundaries meet or cross a road or the boundary of the forest, some mark, such as a board on a post or tree or a stone pillar, should be put up, indicating the name of the block and the numbers of the compartments which it divides.

These boundaries should also be entered on the map of the forest, and a record of each block and compartment should be kept in a separate register, in which not only their boundaries and respective areas are entered, but a description of the stock and of any operations carried out within them. If a working plan of the forest has been made, this register will show what operations are prescribed by it, and how they are being carried out.

I have not said anything about fencing the boundaries of the forest in this chapter, because I have already dealt with the subject in a former chapter, and because, with the huge areas which usually have to be dealt with in the Tropics, the cost of fencing or putting up walls is often prohibitive. The existence of fences in forests where fire protection has to be carried out would be a hindrance rather than a benefit in many cases.

After boundary lines have been cleared, they will

ultimately get overgrown, or the branches of the trees alongside will fill up the gap. It is therefore necessary to go over them as often as required in order to keep them clear, and at the same time to repair any boundary marks which have been damaged.

CHAPTER II

FIRE PROTECTION

In the first part of this volume (Chapter V., "Man and Domestic Animals") I have already discussed the advantages and drawbacks of fire protection. It is now assumed that, after due consideration of the merits of the case, it has been found desirable to protect a forest from fire.

The first step to be taken is to isolate or insulate the forest so that no fires can enter from outside, and the next to subdivide the forest, if it is of an area sufficient to do so, into a number of blocks, each of which, in its turn, is insulated in order to prevent fires which have penetrated from the outside from spreading beyond them into other blocks, or to confine fires which have originated within the forest to as small an area as possible. This insulation is effected by means of *fire-traces*, or *fire-lines*, as they are more commonly called, those on the boundary of the forest being called *exterior* fire-lines, while those which run through the forest itself are *interior* fire-lines. Natural fire-lines may be formed by sheets of water of sufficient width, such as rivers or lakes, by perpendicular cliffs, dense belts of evergreen trees, etc.[1] Roads and boundary lines may also act as fire-lines, but usually they require an additional strip of protecting line, sometimes on one side only and at others on both sides.

[1] Fernandez, *op. cit.* Book III. chapter i., "Fire Conservancy," goes very fully into this subject. He mentions swamps as possible natural fire-lines. But to one who like myself has seen the vast swamps of the Nile overrun by great fires, it is difficult to add them to the list.

Artificial fire-lines consist of one or two *guide-lines* and of the *trace* proper. The guide-line is a cleared line which is used as base, from which the trace is fired, and which should be of sufficient width to enable workmen to prevent the fire at the time of firing from crossing it into the forest. There will be only one of these when there is no objection to the fire extending in one direction. There will be two guide-lines, of which one may be formed by a road, boundary line, or clear bed of a watercourse, whenever the fire is intended to be confined within the bounds of the trace.

The guide-line is always cleared of trees, grass, and overhanging branches, and all stumps should be stubbed out. The trace is usually cleared of trees and stumps, but the grass standing on it is burnt under supervision. Sometimes the trace is not cleared of trees. No doubt the cutting down of trees favours the springing up of grass, which might have been kept down had the trace been kept under full leaf-canopy, and by clearing the trace, especially if it is a broad one, a considerable area may be placed out of timber-production; but the general opinion of foresters is in favour of cleared lines, not only because less dead leaves and broken dry twigs fall on and litter the trace, but because there is less danger of fire crossing a line by way of the crowns, in which there is always some readily inflammable matter, such as dead branches, hanging birds'-nests, or, at higher altitudes, festoons of moss. The grass on open lines also usually dries earlier than that in the adjoining forest, and can be fired with less risk of a conflagration spreading beyond the line.

When clearing the guide-line, all the grass which is cut is thrown along the edge of the trace and pressed down away from the guide-lines. It thus forms a cushion of dry grass, which makes it easier to start burning the trace, which might otherwise be difficult to set alight uniformly, as some portions of the grass in the lines always remain green longer than in others. This is especially the case in depressions where there is

more moisture either in the soil or in the atmosphere. Some writers advocate throwing part of the grass from the guide-lines on the forest side. The object of this is to provide material for quickly starting counter-fires in cases of conflagrations within the forest. This may be possible in certain forests, but in others, especially those liable to be exposed to shifting winds, it would make the line burning become a very difficult and risky job, as any spark flying back would be apt to set fire to the forest.

The trees which have been felled on the guide-line and the stumps which have been extracted should be removed out of the forest and sold, if possible; but if there is no sale they should in no case be allowed to remain lying either on the guide-line or on the trace, where they would become constant sources of danger in the dissemination of fires, but they should be removed some distance into the forest, and far enough not to be set alight when the lines are being burned.

All dead leaves, twigs, and other inflammable débris which are lying on the guide-line should be swept against the trace. It is evident that leaves, etc., will always be falling on the guide-line, but all efforts should be made to have it as clean as possible by the time the trace is set fire to.

The same rule regarding trees felled on a cleared trace applies as with respect to those on guide-lines. They should be removed out of the danger zone, if possible to a safe place out of the forest, and efforts should be made to dispose of them. The grass on the trace is not usually cut, but in some districts it is pressed down from the guide-line some way in towards the centre of the trace. This renders it more inflammable, and makes the burning easier. It may also be useful in the case of interior fire-lines to cut cross lines from distance to distance in order to check the too great impetus of the flames. Such lines are also useful for stopping the burning of the line, should the time or weather be adverse to the continuation of the work.

Fire-lines may be made entirely artificially, by cut-

ting through the forest, or wherever possible advantage may be taken of natural features which may save the expense of cutting. For instance, a broad river or other sheet of water may in itself take the place of the fire-line, or, if narrow, it may take the place of a guide-line. Precipitous cliffs may occasionally serve as fire-lines, but only if not festooned by grass or creepers or other inflammable matter. Roads may in some cases serve, but if there is any traffic on them, and consequent danger of fire being set alight in the forest owing to carelessness on the part of passers-by, it will be necessary to have either two fire-lines, one on either side of the road, or, if the traffic is not great, at least one to leeward of the road.[1] In mountainous countries, where the roads are not running straight down the slopes, the fire-line, if only one is made, will be on the side above the road. In such cases the road can be used as one of the guide-lines. Ridges and spurs of mountains are frequently used for running the fire-lines along them. When only one side of the ridge is to be preserved against fire only one guide-line is required, which is cut on the side of the ridge which is to be protected, and the fire is then allowed to spread up to and beyond the ridge; but if both sides have to be fire-protected, guide-lines will have to be cut on either side of the ridge, the trace being on the ridge itself. When fire-lines run down steep spurs, the guide-lines may have to be supplemented by zigzag paths to permit the easy progress of the fire-gangs. If, then, these paths have to be made right across the face of the trace, each portion contained within two turns of the path can be fired separately, and the risk of spread of fire in difficult places will be minimised. Railway lines passing through a fire-preserved forest will require fire-lines on either side; this is necessary on account of danger from sparks from the engines which might set the whole forest ablaze. If

[1] Fernandez (*op. cit.* p. 443) says that in such a case the fire-line should be on the side from which the wind blows, *i.e.* to windward. The reason given is that until the line is fired the road serves as a fire-break, and when it is burnt as a good guide-line.

possible, fire-lines along the foot of a very steep slope or along bottoms of ravines should be avoided, owing to the difficulty of burning the fire-lines without setting fire to the overhanging mass of vegetation.

As regards the width to be given to the guide-line, it will depend chiefly on the nature of the vegetation to be fired, on the trace, on the strength of the prevailing winds, on whether the trace is cut in the direction of these winds or across them, and also on the composition of the soil and on the gradient.

It is by no means necessarily the tallest grass that is most readily inflammable. In such grass the flames ascend to a greater height and sparks may be carried farther, but the flames usually progress comparatively slowly among the giant grasses or sedges; it is the short, wiry, rather sparse grass along the tops of which the fire will run, sometimes with great rapidity. Such grass is often found on sandy soils which, owing to their loose texture, are full of air, and on getting warmed fan the flames to still greater activity. When a fire-line is cut across the direction of the prevailing wind, it may be necessary to make the guide-line to leeward of the trace wider than that to windward of it. In the same way, when the line crosses a steep slope horizontally or obliquely, it may also be advisable to make the upper guide-line broader than the lower. Thus local circumstances and a knowledge of them must help in determining their width. For ordinary purposes, however, the width of the guide-lines may be taken as more or less equal to the height of the adjoining grass increased by 1 metre (3 ft.).[1]

The width of the trace will also depend on the factors stated above, on the amount of labour available in case of an outbreak of fire, and, in the case of exterior fire-lines, on the nature of the surrounding country. If cultivation, or land bare of vegetation, or green pastures extend right up to the boundary of the forest, the same width of line will not be required as

[1] Fernandez, *op. cit.* p. 448.

where it adjoins forest of equally inflammable nature, or dry savannahs, or marshy land with inflammable reeds and sedges. All exterior fire-lines should be made wide enough to prevent even violent fires to cross them and thus enter the forest. It is true that in some localities it is difficult to make the lines broad enough without sacrificing a very large area. In the coniferous forests of North America sparks are sometimes carried enormous distances, and it is difficult to devise fire-lines broad enough to make the forests perfectly safe; in the Tropics the fire may perhaps be carried through the air for a quarter of a mile, but, as it is impossible to make fire-lines of this width, except where wide river-beds or torrent-beds happen to exist at convenient places, the lines should be made as reasonably wide as possible, and the remaining odds of safety must be confided to the care of an efficient fire-patrol. In India fire-lines over 100 ft. (30 metres) broad are not often made, and they may be of lesser width.

Interior fire-lines may be made either to protect the forest from fire which may originate from within, such as by sparks from railway engines, from travellers along roads, and in forest camping-grounds, or they may be meant to serve as bases from which to counter-fire in case fire enters into any one block, and thus, by sacrificing this particular block, to save the rest of the forest. Such lines, when meant only for counter-firing, may be of different width, but are usually comparatively narrow, and may even be reduced to the width of guide-lines and nothing more. In a large area of forest it is usual to have a few broad interior fire-lines, even where there is little traffic, in case the fire crosses the ordinary lines made for counter-firing in spite of all efforts made to stop it.[1]

The best season for firing the lines is when the grass standing on them is sufficiently dry to make it probable

[1] For an example see map at p. 440, vol. xxxi. No. 8 of the *Indian Forester*, showing the forests of the Mandui Range of the Bombay Presidency. On this map will be found exterior and interior fire-lines 100 ft. broad, and interior fire-lines 60 and 30 ft. broad respectively.

that the first firing will sweep them clean. There are very few lines on which the grass will dry homogeneously; small depressions in the ground, which during the wet weather may serve as overflow channels for carrying off the water, or small pans in which the water has stood longer than elsewhere, or which are the recipients of heavier dew, may contain grass which remains green much longer than that on better drained soil. If there is much of this grass the firing may be somewhat delayed, but it must be remembered once again that the strength of a chain is that of its weakest link, which in this case is represented by strips of dry grass running across the width of the line, and that fires have a way of discovering these weak links and of breaking through them. If, therefore, there is any danger of fires coming in from outside, firing of the lines may be commenced, all the dry portions being burnt at the first firing, the green patches being dealt with afterwards as soon as they are dry enough to burn. Sometimes the withering heat of the flames dries even fairly green grass sufficiently for it to be consumed even at the first firing, and a certain amount of help can be given to them by widening the guide-lines at these points, and thus throwing a thicker cushion of inflammable grass on the edges of the trace. By pressing or rolling the grass down it is also more easily set on fire.

If the traces have been cleared of trees and other woody growth, it generally happens that the grass on them dries earlier than in the forest, and that the firing can be started while the latter is still moderately green, and that the danger of fire entering into the forest during the firing of the trace will be minimised. Still, this is a factor that can be relied on by no means in every case. In forests composed of trees with light foliage and which are shade-avoiding, as *e.g.* several species of *Acacia*, or in savannah-forests, the grass outside the lines becomes inflammable practically as soon as that on the lines; and in cases where the forest has been successfully protected against fire for one or more

seasons, there is, under the living grass, a dense cushion of dry grass of former seasons which is as inflammable as tinder, and is thus at least as easily set alight as the grass on the line.

A calm still evening is usually the best time of the day to commence firing, unless the dew is so heavy that it will prevent the fire from burning. The advantage of starting at near sundown is that it is usually the stillest part of the day, and that there is less danger of wind carrying sparks into the forest; it has the additional advantage of making sparks visible to the eye. This is a great advantage, for it permits of their being followed, and if they fall into the forest they can be stamped out at once. In the fierce sunlight of the Tropics sparks cannot be seen, and the first notice of their flight may be obtained by seeing fire and smoke rising from the forest. A slight fall of dew may also be helpful by bringing the fire under easier control; but if it be so heavy that the burning becomes irregular and many patches of grass remain unburnt, the firing should be stopped at once and resumed on the first suitable occasion.

The firing is carried out by a gang of men under the supervision of a responsible forest official, who directs the operations, decides the proper time for starting and for closing work, prescribes any modifications in the routine of firing, and takes measures to repress any fire which may cross the guide-line into the forest. In the Indian forests this work is usually carried out under the supervision of a ranger, and, as often as possible, a supervising officer is also present. To young forest officers going out to the Tropics I would recommend as frequent attendance as possible at the firing of the lines within their forests. The ranger in charge may be a man of great experience, who may know all the tricks by which a fire may be circumvented. Nevertheless, although his superior officer may have little or no experience, it is a comfort to him to have him present to take the responsibility. Southern races often dislike responsibility, and if they are saddled with it they are

apt to lose their heads, while they will remain cool and collected if somebody else is present to take that. The superior officer in his turn will garner knowledge and experience, which will always be useful to him during his service.

The number of men to be employed for a firing gang will depend on whether the line has only to be fired from one side or whether it has a guide-line on either side, on the width of the line, on the configuration of the ground, on the nature of the grass, soil, and inflammability of the grass in the adjoining forests, on the aptitude of the men, on the fickleness of gusts of wind, and on the direction and straightness of the guide-line. For it is evident that, if the line has to be fired from both sides almost simultaneously, more men will be required than if the flames are allowed to spread as far as they can go on one side. The varying faculty of different grasses to catch fire and, so to say, to run away with it, and the assistance to such inflammable grasses given by porous soils, has already been alluded to, as has the nature of the soil covering in a forest which has been previously protected. It is also clear that, in places where the wind is liable to shift, as may often be the case, especially when the line runs along the bottom of a winding valley with smaller side valleys debouching into it, more men are required for emergencies. Likewise, a wide line presenting a larger sheet of flame, or one running across a slope, or one which follows the curves of a winding stream which serves as a guide-line, requires special precautions, and so does one across which the prevailing winds are blowing. Finally, a well-trained gang not only knows better how to control the fire, but is less likely to be seized with panic whenever the fire appears to be getting out of hand, and, to an inexperienced eye, it often seems impossible to check it. For this reason it is to the advantage of the forest officer to recruit his workmen for this purpose from neighbouring villages, if there are any. Not only will the villagers thus

acquire a pecuniary interest in fire protection, but risks from incendiarism from people who grudge giving up a grazing-ground during the fire season would be minimised, and the men living close at hand would be employed year after year, and would thus become expert workmen. They would also be handy for putting out any fire which got into the forest.

Fernandez[1] gives the strength of a firing party, when the trace is on level ground and the fire is to be controlled from one side only, as from six to ten men, when conditions are not unfavourable, and from ten to twenty men when the fire has to be prevented from spreading on both sides of the lines. In the places where my own experience has been gained, this number was usually considered too small, and about double the number of men stated above were employed.

Before starting the firing, each man should be provided with a broom to beat out the flames and to sweep burning embers or leaves from the guide-line on to the trace. In India it has been found that fronds of the Dwarf Date-palm (*Phoenix acaulis* and *P. farinosa*), tied together in a bunch of a size to be comfortably held in the hand, give the best results, as they last a long time. If such or similar fronds are not obtainable, stiff wiry twigs, bearing leaves which do not easily come off, should be employed; but even in this case the brooms soon get battered, and one or two men will have to be employed in making new ones to replace those which have become useless. Men also usually hold in their other hand a bunch of leafy twigs, which they hold before their faces while beating out the flames to screen them against their scorching heat. If running streams or wells are not frequent along the line of work, provision must also be made for a supply of drinking water, for the work soon gives the men a parching thirst.

On arriving at the point from whence the trace is to be fired, the men arrange themselves along the

[1] *Op. cit.* p. 466.

line at distances from each other sufficient to enable them free room for swinging their brooms and beating out the fire. One man then takes up a bundle of dry grass, and holding it at one end, sets fire to the other end. He then trails this burning end along the cushion of cut dry grass lying on the trace side of the line and takes it along as far as the last man on the line. He then turns at right angles towards the centre of the trace, still setting fire to the grass, and at last drops it near the middle. The men on the line wait till the dry cushion of grass is fairly well consumed, and allow the adjoining grass on the trace to catch fire properly, before they begin to beat out the embers. They merely beat out flames which are trying to creep across the guide-lines by means of fragments of dry grass or stubble. If the wind is blowing towards them they must begin beating a little earlier. The flame in heating the air above it and causing it to rise always creates a draught, but on a still day the draught will follow the flame.

When the trace has to be fired from both sides, these are not usually set alight quite simultaneously; the one on which there is most apprehension of a contrary wind should be fired first, and the other side should be started only after the first has advanced well into the trace. The same remark applies to lines which run across steep slopes. In this case the upper line will be fired before the lower. It may also be necessary to have a stronger party on the side on which there is greater risk than on the other.

The firing should always be against the wind—that is, if the wind blows straight down a line the firing should be begun at its lee end; if straight across, on the lee guide-line; and if slanting, at the lee end on the lee side. Fig. 87 gives an example of a fire-line on which the wind blows in a slanting direction. The firing is begun in the strip marked 1. When this has been well started, the strip opposite to it, marked 2, will be started. It will be observed that it is made to overlap

slightly strip No. 1, in order to check the progress of the flames at the end of that strip. When the embers on strip 1 have been well beaten out, and those from strip 2 have met it and there is no more danger of flames breaking back, the firing of strip 3 is begun, that of strip 4 following it as soon as strip 2 is safe, and so on.

If the trace is very broad, it may be an advantage to run a bundle of burning grass down the axis of the trace. This checks the impetus of the flames and prevents too strong a draught from following them from the guide-lines. Following the firing gang there must always be one or two men whose duty it is to

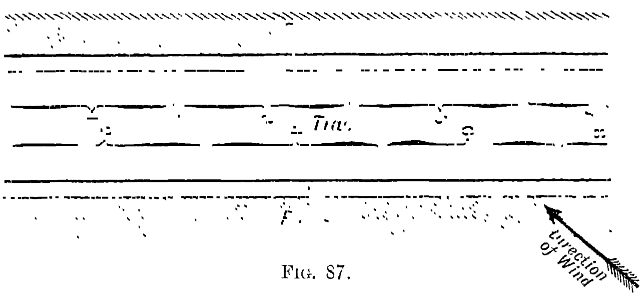


FIG. 87.

stamp out any glowing embers which have been overlooked, and to sweep from the guide-line on to the trace any inflammable material which might allow fire to cross it. They must also watch sparks carried into the forest, as well as burning leaves and twigs, and must stamp them out at once. In coniferous forests special care must be given to burning cones, and where there are hanging birds'-nests, which are highly inflammable, these should also be watched. I have known of such which were carried right across a fire-line and set fire to the forest on the other side. If a fire-line is made down a slope the firing should be begun from the top of that slope.

Should any fire break across the guide-line into the forest, all efforts should be made to stop it at once.

While part of the gang is left to control the fire on the line, and if necessary to stop it, the remainder will set to work to beat out the flames where they are intruding. It may be possible to master them at once with well-directed blows with the brooms, but, if they have got beyond that stage, it is often not possible to face them at their apex. The beating out of the fire should then be carried out along its edges until the apex is reached. Supposing, *e.g.*, that the fire has broken across the guide-line at points *a* and *c* on Fig. 88, and that it has penetrated into the forest, burning out a wedge *abc*, the beating out should be from *a* to *b* and from *c* to *b*. It may be some time before the fire can be mastered,

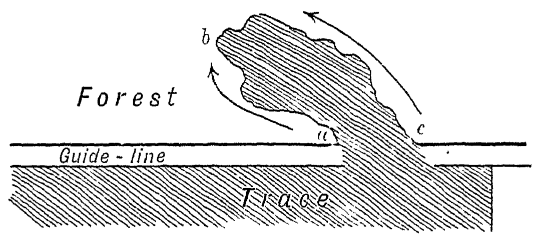


FIG. 88.

and some of the forest may be swept by fire. If it gets entirely out of control, and cannot be so guided as to pass over only a comparatively small portion of the block, counter-firing will have to be resorted to. This may be started from one of the interior fire-lines; or, if time allows, it may be possible to hastily cut a guide-line from which the counter-firing may be started; or advantage may be taken of existing roads, watercourses, or even footpaths from which to start the counter-fire.

From the time when the fire-lines have been burnt, they are put under the care of a temporary establishment of fire-watchers, whose duty it is to patrol them, sweep away from the guide-lines any dead leaves, twigs, or other inflammable substances which may have fallen on them. These should be swept into small heaps in the centre of the trace, and these heaps should be set fire to

under control before they have time to assume large and dangerous dimensions. In the same way, small patches of grass which have escaped the burning should be set alight when they are dry enough to burn, and if considerable masses have been spared by the first firing, a firing gang will have to be brought back for a second burning as soon as it is ready for it. Each watcher should go round his beat at least once a day, and at dangerous times, as when there are many fires about and a high wind is blowing, it may be necessary for him to stay on the line where there is most danger to be apprehended. The beats should therefore be of such a size as will enable the watchers to do their patrolling efficiently. The following description, taken from the *Indian Forester*, will give a good idea of one of the methods of patrolling :—[1]

"Temporary huts are constructed on the lines for the housing of the fire-watchers, at a distance of 3 to 5 m. from one another, these being large enough to hold two fire-watchers and occasionally a forester and his servant sleeping in them.

"Temporary wells are dug close to the huts and are repaired annually at small cost by hired labour, or by the watchers themselves as soon as they are employed. After completion of this work, the work of ticket-patrolling and sweeping dead leaves on the lines is commenced.

"The patrol-tickets are pieces of paper about 3 to 4 in. square, with the name of the hut from which they start, and the date and signature of the range officer written on them. A known number of these tickets is left in the starting hut of each block. The tickets are started in the morning from the starting huts of all the blocks, and are carried round the blocks by watchers from hut to hut. The patrolling is so arranged that the tickets from all the blocks meet at a convenient hut in the centre, in the afternoon, as

[1] "Fire Protection on the Ticket-patrol System," by D. N. Avasia, in *Ind. For.* vol. xxxiv. No. 11.

explained in the sketch below (Fig. 89), from whence they are all taken to the range office.

"I., II., and III. are blocks; A, B, and C are huts from which the patrol-tickets *a*, *b*, and *c* are started in the morning. The tickets are carried round the blocks in the directions shown by the arrows until they all meet at hut D, from whence they are sent to the range officer.

"The foresters or senior guards in charge of the

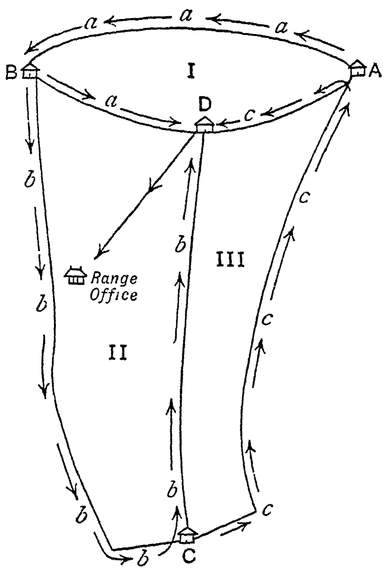


FIG. 89.

blocks see that the tickets are carried round regularly each day, and inform the range officer of what is happening in the forests and in the surrounding private lands by separate reports submitted along with the patrol-tickets. The range officer thus gets all the news regarding the fire protection of the forests in his charge daily in the evening at his headquarters, where there are a number of men always available for help in case of a fire occurring in the forests. As he finds time he pays surprise visits, sometimes at night, to

see if the foresters and watchers are at their stations and are doing their work properly, and also that the right number of tickets are at the starting huts.

"The ticket-patrolling of lines is done in turn by one of the two watchers attached to a station, and means about a couple of hours' work for him each day. For the rest of the day the watchers are engaged in sweeping dry leaves off the lines, collecting them in beds of watercourses and other safe places, and burning them at night. By the time the hot weather is well set the sweeping has been completed and the lines have a 6-in. growth of green grass on them. About this time fires in private forests are seen in the distance, and the range officer organises parties of labourers, and, with the assistance of foresters in charge of the blocks, counter-fires the private forests from the external lines of his reserve. In about four or five days the fires started by the Forest Department meet the other fires and the fire burns out at a safe distance from the reserve, and in this way the Government forests are secured from external danger from fires for the rest of the season. After this the fire-watchers keep taking the patrol-tickets round, and guard against danger from fires starting within the reserve by keeping a careful watch on the persons passing through the forest. When the rains have regularly set in and all danger from fires has entirely disappeared, the fire-watchers are paid off."

Ticket-patrols are not used in all Indian fire-protected forests. The patrolling has always to be done, but the supervision of its execution depends on the activity and trustworthiness of the permanent staff. In many forests other forest works languish during the hot weather and the regular staff has more time to devote to inspection. The above account was written by a range officer, and no reference has been made to the administrative officer in charge of the forests, who should be particularly active during the dangerous season; he should constantly inspect lines and see

that the whole machinery is working smoothly. Arrangements should be made by which he can be informed at once of any fire breaking out in the forest or in dangerous proximity to it. No doubt a system of telephones would be the best, but this cannot always be done on account of expense. In some places a red envelope with the name of the fire-station written on it is sent to the officer in charge, and this informs him of any fire which has broken out in that block. If the fire is located within a distance which can be reached quickly, the officer should always make it a point to go at once, whether it be day or night.

In many places watch-platforms are erected near the fire-stations. These platforms are usually put up on high trees or on high ground from which a clear view of the forest can be obtained, and rising columns of smoke can also be located. On these there must be a man on watch day and night. If a fire is noticed a message must be sent at once to where labour is obtainable to put out the fire. At some of these stations a kettledrum is kept which is beaten as soon as a fire is noticed. By giving single beats at the end of each tattoo the number of the block in which the fire occurs can also be proclaimed, and help can be at once sent to the block indicated. At some stations, during the daytime, a white flag is flown to show that all is well, and a red flag if a fire has been marked.

Apart from these works, measures must be taken to prevent people bringing fire into the forests. Notices should be put up along the boundary lines and along all roads entering the forest warning people against bringing or lighting fires within them. If the forest is a Government forest, special laws will have been enacted making it an offence to carry or light a fire within the forest, and prescribing the roads by which alone the forest may be entered except with the permission in writing of the officer in charge of the forest. Private owners have usually to rely on the ordinary criminal and civil laws in force in the country. It

is also necessary to warn all villagers, especially those having rights or privileges within the forest, and all contractors whose men come in, of the consequences which they will have to bear in case of contravention of the regulations.

In appointing the temporary establishment of fire-watchers, preference should be given to the inhabitants of neighbouring villages. This gives them an interest in fire protection, especially if, with successful protection, small privileges are granted to them, such as pasturing their cattle within the forest, collection of dead and fallen wood, or access to a spring. They must be made to understand that want of assistance or obstruction on their part will lead to the suspension or cessation of rights and privileges.

In Government forests the law also usually provides that all right or privilege holders and all men employed on forest works are bound to give information and help in case of fire, and that if they do not give this assistance they render themselves liable to various penalties. If, however, the help has been given willingly and cheerfully, it is not bad policy to give them some small reward for it.

For all forests, maps should be kept in the office of the forest officer in charge, one for each season, showing the area over which protection has been attempted, the fire-lines and their widths, the fire-stations and, by means of a colour wash, the portions which have been burnt over. The area and date of the conflagration should be noted over the wash, in Indian ink, together with a remark whether the burning was mild or severe. In this way a very clear history of the protection of the forest is obtained, and the after-effects of a fire can also be watched.

CHAPTER III

FIXATION OF SHIFTING SANDS AND OF UNSTABLE SLOPES

SHIFTING sands may be divided into two classes, viz. *coast-* and *inland*-dunes, the first being caused by sand thrown up by the sea and blown inland by the wind, while the others are caused by the disintegration of soft sandstone rocks by torrential rains and wind, or by wind alone. These are also driven forward by the prevailing winds and form billows of sand, which, in advancing, often cover wide extents of country, drifting even over the tops of well-marked hill ranges.

The best-known example of coast-dunes are the Dunes of Gascony, stretching from Arcachon to near Bayonne, and which, thanks to the genius of Brémontier, who started the work at the close of the eighteenth century, have been consolidated and turned into forests of *Pinus maritima.* Of inland-dunes, those of the Sahara and its extensions into the Libyan and Nubian deserts are the best-known examples.

In the Tropics *littoral* dunes are not usually, if at all, as extensive as those of Gascony. There have been cases, however, as near Madras and near the mouths of the Indus near Kurrachi, where wind-driven sands have been a source of danger. The sand-drifts have been checked by the planting of sand-binding plants. Near Madras plantations of *Casuarina* have effected this, with the help of other sand-binding plants which have the faculty of giving out a network of prostrate branches or underground creeping rhizomes, which

not only branch and branch again, but give out fresh roots at the nodes and thus hold the soil. The best known of these are the *Ipomaea biloba*, a Convolvulaceous plant, and the *Spinifex squarrosus*, a creeping grass with globose heads. To these may be added *Cyperus arenarius*, *Canavalia obtusifolia*, *Hydrophylax maritima*, *Spermacoce hispida*, *Launaea pinnatifida*, *Pupalia orbiculata*, and *Pandanus odoratissimus*.[1]

In Ceylon the same plants are to be found, with various shrubs, such as *Scaevola Koenigii*, *S. Lobelia*, *Clerodendron inerme*, *Azima tetracantha*, and the Palmyra Palm (*Borassus flabellifer*). These, in most places, spring up in sufficient abundance to check the march of the dunes before they have got beyond a second range of hillocks. On the sandy shores of the Red Sea numerous plants belonging to the natural orders Chenopodiaceae and Zygophyllaceae keep the soil together, as well as *Statice axillaris*, *Bergia suffruticosa*, *Cyperus cruentus*, and creeping grass, *Aelurops repens*.

It may be necessary to take more elaborate measures to fix the invading sands, and the method adopted in the French dunes will now be described.

The first step taken is in erecting, at the foot of the outer line of sand-hills, or rather between it and the sea, close on the beach above high-water mark, a long row of boards, not unlike thin railway sleepers in size and appearance. These boards are stuck firmly into the ground, so that they may not be overturned by the pressure of sand and wind. They are not set in touching each other, but a short distance apart, the space between them being about $2\frac{1}{2}$ cm. (1 in.). This not only reduces the pressure from wind and sand, but it allows a certain quantity of the latter to trickle through the apertures, as it gets accumulated on the windward side, and thus to enlarge the base of the new

1 "Sand-binding Plants," by V. Subramania Iyer, in *Indian Forester*, vol. xxxv. No. 2.

outer dune which is being formed. A second row of boards or a wattle-fence is also sometimes erected between it and the outer dune, to prevent the sand which has drifted through from spreading over the dunes. As soon as this is done, the outer range of sand-hills is covered with leafy branches, the butt-end of which is stuck into the sand to windward, the leafy end resting on the ground to leeward. This is done to prevent the wind from overturning the branches and scattering them. At the same time as the branches are put down, seeds of sand-binding grasses, such as *Psamma arenaria*, of broom, gorse, and of *Pinus maritima* are dibbled into the ground. After some time these begin to germinate and to hold the soil.

FIG. 90.

The *Psamma* has also the advantage of being able to give out fresh roots from upper nodes as the sand gathers and covers the lower part of its stem, and thus it helps still more in holding it.

In the meanwhile sand gathers against the row of boards, and ultimately covers a great part of them. They must then be drawn out far enough to offer a fresh obstacle to the moving sand, and this goes on until a new outer dune has been formed, which, in its turn, can be taken in hand and afforested, the palings being put in at its foot next to the sea. While it is growing, the rows of dunes inland can also be afforested, and after a time the work will be restricted to the new rows of outer dunes which get formed on the seaside. Fig. 90 illustrates the description given above.

With *inland*-dunes and smaller masses of shifting sands, the question of how to deal with them is a more complex one. It has already been seen in the first part of this volume (Chap. III., "Locality") that it is mostly in regions of extremely small rainfall that these sand-drifts are the most difficult to stop, and that where there is a sufficient precipitation of moisture the vegetation soon springs up on them and fixes them, unless interfered with by man or domestic animals. The example given is of the sand-drifts in Kordofan in the Western Sudan, which have been covered by open forests of *Acacia Verek* and with herbaceous growth, the most prominent of which is the *Cenchrus catharticus*, a grass with hooked seed-capsules forming most irritating burrs, which help its distribution.

But the work of Nature, unaided, is often slow, and it may be that for some cause the onward march of these sands must be arrested. The first step will be to exclude all animals from the area, so that the surface may not be constantly broken up and young plants destroyed. If the rainfall is sufficient, the measures for fixing the sands may generally be of a fairly simple nature. In Europe open wattle-fences of sufficiently loose texture to offer not too strong a resistance to wind and sand are erected, and made stronger by means of struts, and the area is loosely covered by sods of turf, which are either scattered irregularly over the surface or arranged in a chess-board pattern of hollow squares, in the middle of which seeds of trees, shrubs, or sand-binding grass are dibbled in. In the Tropics, instead of wattle-fences, thorn-fences or "zaribas" may be used. These consist of piled-up masses of thorny branches which resist a considerable pressure from the wind, as the sand soon trickles through the interstices of the branchlets and fixes them in the ground. If the wind is particularly strong their butt-ends can be turned towards the wind and stuck into the ground, the leafy ends being to leeward. These fences soon become crates full of sand, and they must be added to as they grow. As the fences are

completed, seeds are dibbled in all over the area, which is also irregularly covered by loose branches which can be stuck into the ground as indicated above.

If it be possible, the afforestation of the area from which the sand is derived should also be taken in hand so as to stop the source of supply.

In order to effect a successful afforestation of the sand-swept areas, and thus to arrest the movement of these sands, a study of the plants which thrive in these conditions should also be made. In Kordofan, for example, besides the species mentioned above, I have noticed on these sand-hills, among the trees, *Acacia spirocarpa*, *A. albida*, and *Albizzia amara*; among the shrubs, *Leptadenia Spartium* and three species of *Boscia*; among herbaceous plants, fatty plants belonging to Zygophyllaceae and Ficoideae, and numerous grasses, a large portion of them belonging to the genus *Aristida*.

In districts with an unappreciable rainfall the question of how to fix sands is one of extreme difficulty. Where the sand does not shift, a number of plants manage to keep themselves alive for at least part of the year; they evidently germinate very easily, for the amount of moisture available for this purpose is extremely small; but on the dunes themselves there is often no trace of vegetation of any sort. In the Dongola province of the Sudan I have searched for plants which might help in fixing the sands which invade much of the cultivation. The most hardy plants found by me have been two grasses, *Panicum turgidum* and *Aristida plumosa* var. *berberica*, and a woolly, semi-woody plant, *Aerva tomentosa* var. *Bovei*. In such places the problem of how to fix the sands has not yet been solved; it can, no doubt, be arrested temporarily by means of fences and scattered branches, and it is possible that when in this arrested condition some of the desert plants might be induced to spring up. Among these may be mentioned those quoted above, as well as the desert-acacia (*A. tortilis*); *Leptadenia Spartium*, which may grow into a small tree; semi-woody herbs, such as

various species of *Aerva*; succulent and prostrate herbs, such as *Limeum viscosum*, *Zygophyllum* spp.; other herbs of the same natural order, such as *Tribulus* or *Fagonia*; sedges, such as *Cyperus cruentus*; and various grasses, such as several species of *Aristida*, *Andropogon*, *Cenchrus*, *Pennisetum*, *Tetrapogon*, and *Aelurops*; while on the edges of depressions, especially edges of streams or rivers where the sand pours into them, *Acacia arabica*, *A. albida*, and the Egyptian halfa grass, *Desmostachya cynosuroides*, can be made to spring up.

To prevent the sand from encroaching on fresh land thorn fences can be set up, as described before. In the Northern Sahara the natives keep the encroaching sand from their cultivation by diverting it by means of low mat fences, made of woven grass or palm leaves, which are set obliquely to the wind and thus deflect the current. In Upper Egypt and Northern Sudan, the flooding of the land and subsequent cultivation works off the top layer of sand, but this requires an abundant supply of water during part of the year at least.

As regards some of the grasses mentioned above, it is, I think, desirable to state that, in countries where camels are commonly used, the *Spinifex* grass, although a good sand-binder, is objectionable on account of its globose spinescent seed spike, which is very apt to give camels sore feet. The *Cenchrus catharticus*, although a terrible nuisance to passers-by, owing to its hooked awns, which catch in the clothing and are apt to distribute themselves over all parts of the body and to give unpleasant sores, is a favourite fodder of the camel; indeed, in time of scarcity, the natives eat the seed.

It is evident that, while an effort is being made to fix shifting sands, all traffic or grazing over the portions taken in hand should be excluded.

Fig. 91 shows drift-sand pouring over the banks of the Nile in the Province of Dongola, and covering up the strip of cultivable land above water-level.

Like many inland-dunes, *unstable slopes* are largely the result of deforestation or removal of other vegetable

covering over slopes which are particularly liable to erosion. Only in the latter case the erosion is caused by water which scours the surface of the slopes, or, after sinking into a friable soil, soaks it to the point of saturation and then bursts out in a torrent of liquid mud, thus forming a landslip. It may also be caused by springs or watercourses, the waters of which run down or under-

FIG. 91.—Shifting sands pouring over the banks of the Nile, Dongola Province, Sudan.

mine unprotected slopes and, either gradually or in sudden bursts, carry away their banks. Railway cuttings or roads cut on a hill-side or quarries may also be the cause of slips by the removal of the foundations on which the surface layers rest.

These landslips not only cause a direct loss of productive area, the loss being constantly increased unless protective measures are taken, but the detritus washed down into the valleys or plains below spread out like fans, and may cover with rubbish other fertile areas,

such as arable land or pastures. In the Alps, especially in France, the damage caused by landslips due to the baring of the slopes, particularly by unlimited grazing, has resulted in the State taking effective steps to consolidate and reafforest the mountain slopes whose débris were causing immense damage in the valleys below them. In the Tropics the same results have been obtained from unchecked grazing and browsing, and from lack of fire protection. The pages of the *Indian Forester* are full of complaints from foresters regarding the lack of measures to protect the catchment areas of several important rivers, but unfortunately very little has been done so far, except perhaps near hill stations, whose very safety has been endangered. Thus, after a landslip, which cost several lives and did considerable damage to property in the year 1880, at Naini Tal, the summer capital of the United Provinces in India, extensive works of consolidation and drainage were carried out by Mr. (afterwards Sir William) Willcocks, and the cutting of trees and pasturing of cattle and browsing by sheep and goats were prohibited.

The operations which have to be undertaken for consolidating unstable slopes may vary greatly according to the nature of the soil, the exposure to wind during rainy weather, and the amount and nature of the rainfall. In some places mere protection from fire and exclusion of grazing and browsing animals will have the desired effect, particularly if fellings are discontinued, or carried on in great moderation, on the slopes. On the southern slopes of the Siwaliks, near Saharanpur, the soil being mostly a very coarse gravel and the gradients generally steep, the mere protection from fire and grazing has resulted in the fixation of the chaotic watercourses. The heaped-up and tumbled boulders have been held up by the vegetation which has sprung up, and the water now flows between well-defined banks covered with and held together by forest of such trees as *Dalbergia Sissoo* and *Acacia Catechu*; while on the slopes which only bear a scattered crop of

trees such as *Shorea robusta*, *Boswellia thurifera*, and *Pinus longifolia*, an abundant crop of grass has sprung up and forms a very fair safeguard against erosion.

But, especially where there are rotten shales and torrential downpours, these measures may not be sufficient. In addition to them, the fellings on the, as yet, still forest-clad portions must be discontinued, or they must be made very carefully on the selection system. In places where a heavy crop of high forest trees may be a danger, owing to their weight, it may be advisable to fell on the coppice system with short rotation,[1] but

FIG. 92.

in this case the fellings should not be made just before the rains, as this would expose the soil unnecessarily. Trees standing on the lip of the wound caused by a landslip should be felled, otherwise they will be liable to be overturned and to cause greater damage, but their roots should on no account be grubbed out.

Efforts should then be made to reclothe the bare slopes with vegetation; but as, on a constantly moving surface, satisfactory results might be difficult to obtain by mere sowing or planting, it may become necessary to do something which will at once give stability to the slopes.

[1] Schlich, *op. cit.* vol. iv.

A simple method of giving a check to the movement of the surface particles of the soil is in pegging down, on the slopes, branches of trees, the butt-end being placed down the slope; or, if small trees or bushes are already growing on it, a method similar to that adopted in hedgerows in parts of England can be employed. The tree is partly cut through and bent flat up the slope and pegged down (Fig. 92). Some trees, when thus pegged down, have the faculty of giving out adventitious roots at the points of contact with the soil, and of thus holding it—in other words, layers are formed. The assistance of cuttings can also be obtained, not only put in all over the surface, as is done with *Robinia* in railway cuttings in Europe, but by using

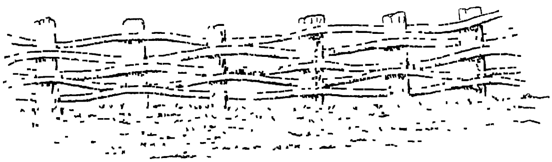


FIG. 93.

them as the uprights for wattle-fences constructed across the face of the slope. There must, of course, be sufficient moisture in the soil to make these cuttings a success. Where there is not, fences are made with posts of strong lasting timber, any long flexible branches serving for the purpose of binding them together (Fig. 93). These fences are put up horizontally along the contours, the distance between the rows of fences varying with the gradient and with the stability of the slope surface. Logs of timber may also be laid horizontally across the slope and made firm by means of strong posts. Where the slope is very steep and the surface very unstable, it will become necessary to have revetment walls of dry masonry. If these have to be made of any considerable height they may be set up in steps, the flat surfaces between the steps being planted up with suitable trees or with cuttings (Fig. 94).

When the fences or walls have been erected, a number of herbaceous plants will begin to spring up and to help in fixing the slopes. Some time is given to them to start thus, and then the slopes should be planted up with strong plants or cuttings, which will complete the work except as regards upkeep.

Where springs exist and their waters run down

FIG. 94.

unstable slopes, they should be trained from their source. In the upper portions it may be sufficient to peg down fascines along the bed and on the sides, but lower down paved channels should be constructed of boulders sufficiently heavy not to be easily torn out by the rush of water. The banks of the watercourse should be strengthened by means of wattle-fences, and from distance to distance flat horizontal paths may be cut out and covered with stone slabs. Fig. 95 gives an example of one of these watercourses which has been

trained in the manner described; it also shows the wattle-fences put up for strengthening the banks, as well as the horizontal, slab-covered paths.

Where the stability of a slope is endangered by a mountain torrent which is constantly undermining its base, its impetus has to be checked by terracing right up to its source. This terracing is done by means of walls built across the bed of the stream from distance

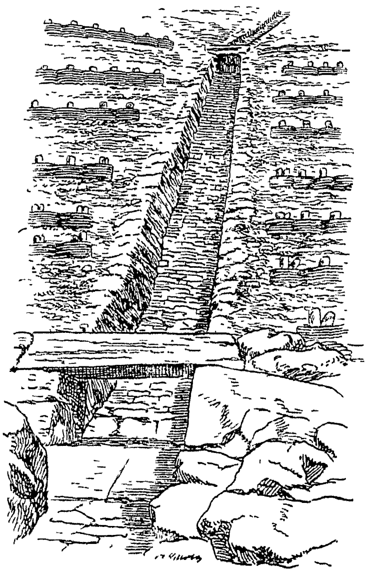


FIG. 95.

to distance according to the gradient, liability to sudden floods, and nature of the soil.

Quite at the top it may be sufficient to substitute live wattle-fences for the walls, but wherever there is sudden strong pressure walls will have to be erected. These walls (Fig. 96) should be put up at carefully selected places, where they can rest against solid bed-rock. Near the top they will be relatively small and simple in construction, but they will gradually become larger as the volume of the stream increases, owing to

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